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SMALL WATER SYSTEM OPERATOR CERTIFICATION

COURSE REFERENCE MANUAL

One requirement of the 1996 amendments to the Federal Safe Drinking Water Act is that owner/operators of smaller public water systems must become state certified. The intent of this requirement is to ensure that the operators of these systems have the necessary knowledge and training to provide a safe and dependable supply of drinking water to their customers.

To meet these requirements, the Wisconsin Department of Natural Resources contracted with the Wisconsin Rural Water Association to produce this Course Reference Manual for small water system operators. It is intended to be used not only as a study guide for the Certification Exam, but also as a comprehensive reference manual containing information on all aspects of waterworks processes and procedures to assist drinking water providers in their day-to-day operations.

Small Water System Operator Certification
The Wisconsin Small Water System Operator Certification process for owner/operators of Other-Than-Municipal and Nontransient Noncommunity water systems will begin late 2001 with training classes and exams held at different locations throughout the state. The classes will consist of 3-4 hours of training, covering information provided in this manual, followed by the Operator Certification Exam. The exam consists of approximately 50 questions on basic water system operation. An operator must correctly answer 75% or more of the questions to obtain state certification. Once certified, an operator must also acquire at least 6 hours of Continuing Education Credits every three years to maintain certification. These credits are acquired by attending state approved training classes on subjects relating to the water industry.

The production of this manual was a cooperative effort of staff of the Wisconsin Department of Natural Resources Bureau of Drinking Water and Groundwater and the Wisconsin Rural Water Association, with input from a Peer Review Committee consisting of individuals from all areas of the waterworks industry in Wisconsin. We would like to express our heartfelt appreciation to everyone who assisted in this process for his or her time and efforts.

DNR Development Team	WRWA Development Team	Peer Review Committee
Corinne Billings	Ken Blomberg	John Berg
Steve Karklins	Scott Giese	Dave Dombrowski
Don Swailes	Ed Hendzel	Michael Furstenburg
Peggy O’Donnell	Joe Kniseley	Robert Harris
Ron Curtis	Jeff LaBelle	David Magnussen
Sandy Heimke	Dick Minett	Art Liebau
	Dave Lawrence	

Chapter 1
Drinking Water Regulation

THE HISTORY OF DRINKING WATER REGULATIONS

Federal authority to establish drinking water standards was first enacted by Congress in 1893 with the passage of the Interstate Quarantine Act. The primary intent of this act was to prevent the spread of disease both from other countries into the U.S. and from state to state. The provisions of the Interstate Quarantine Act were enforced by the US Public Health Service (USPHS) and at the time, only applied to water systems that provided water to interstate means of transportation, such as boats and trains.

The USPHS developed more comprehensive standards for drinking water over the years, including some limits on chemical, physical, and bacteriological contamination. These standards were not mandatory, but they were usually adopted by those states that developed their own requirements for public water systems.

As technological advances were made in the 1960's and 1970's that allowed for better identification and detection of disease-causing organisms and chemicals in water, there was increasing pressure on the federal government to create uniform, nationwide drinking water standards for public water systems. The act that followed was called the ***Safe Drinking Water Act (SDWA)*** and was first passed by Congress in 1974. It has been amended twice since then, most recently in 1996. The SDWA not only sets water quality standards, but it also contains other regulations for the water industry, which are important in protecting public health.

US ENVIRONMENTAL PROTECTION AGENCY

The federal agency responsible for establishing public drinking water standards and enforcing the requirements of the SDWA is the ***US Environmental Protection Agency (EPA)***. However, the EPA can delegate enforcement authority to the states if the state elects to do so. This is called "***Primacy Authority.***" Most states have primacy authority to enforce the provisions of the SDWA in their state. If they do, they must establish requirements at least as stringent as those set by EPA.

WISCONSIN DRINKING WATER REGULATION

Wisconsin has long been recognized as a leader in the protection of natural resources and public health through stringent water regulations. Wisconsin has received approval from EPA to have primacy authority for enforcing public drinking water regulations in the state. These regulations are enforced by the Wisconsin ***Department of Natural Resources (DNR)***. In the DNR, the ***Bureau of Drinking Water and Groundwater*** is responsible for enforcing Safe Drinking Water Act (SDWA) required drinking water regulations.

The DNR not only enforces drinking water standards, such as those in the SDWA, but it is also responsible for establishing and enforcing standards and regulations for water system design, construction, operation and maintenance, well construction and placement, pumps, treatment processes, chemical addition, well abandonment, lab certification, and wellhead protection. To ensure water systems meet these state requirements, water system owners are responsible for obtaining plan approvals from the DNR for well construction, pump installation, well rehabilitation, chemical addition to water, water treatment, and new system capacity. Plan approvals help ensure that water suppliers provide a safe and dependable supply of water to their customers.

DNR personnel assure compliance with all appropriate codes and regulations by performing periodic on-site inspections of each system. These inspections are called ***Sanitary Surveys*** and their frequency depends upon the size and classification of the water system. During the sanitary survey, the DNR representative will review the system's compliance and monitoring records and inspect the water system facilities. Following the inspection, the system owner will receive a written report listing any deficiencies or violations found, and a time frame for the system to correct the problem(s).

WATER SYSTEM CLASSIFICATION

SDWA regulations apply to all public water systems. The most basic definition of a **public water** supply is any water system that serves at least 25 persons at least 60 days per year. Public water systems may then be broken down into two major classes. These classes are ***Community Water Systems*** **–** public water systems that serve **RESIDENTIAL** consumers, and ***Noncommunity Water Systems*** **–** public water systems that serve **NON-RESIDENTIAL** consumers.

Community water systems are further classified into two sub-categories. **Municipal Community (MC)** water systems are residential water systems that are owned and operated by a governmental entity. **Other-Than-Municipal Community (OC, or OTM)** water systems are residential water systems privately owned and operated.

Noncommunity water systems may also be divided into two sub-categories**. Transient Noncommunity (TN, or TNC)** water systems are nonresidential water systems that serve transient consumers. This type of system serves at least 25 persons a day for at least 60 days per year, but those served change from day to day. The second sub-category of noncommunity system is the **Nontransient Noncommunity (NN, or NTNC)** water system. This type of system serves non-residential consumers (i.e. transient), but it serves the same 25 or more people at least 6 months out of the year.

Examples of the different types of water systems include:

Municipal Community water systems: Village, town, or city water systems, sanitary districts, prisons, and residential care facilities that are owned by the State, County, or Municipality and are served by their own well.

Other-Than-Municipal Community water systems: Privately owned mobile home parks, condominiums, apartment complexes, rural subdivisions and privately owned residential care facilities served by their own well.

Transient Noncommunity water systems: Restaurants, taverns, hotels, campgrounds, wayside rest areas, resorts, and churches served by their own well.

Nontransient Noncommunity water systems: Schools, factories, daycare centers, and commercial businesses that have 25 or more permanent employees and are served by their own well.

Legal Definitions of Water Systems
Wisconsin Administrative Code Chapters NR 809 and NR 811 are the primary State Codes used to implement the requirements of the SDWA in Wisconsin. They contain the following definitions:

NR809.04 (57) (a) “Public water system” or ”system” means a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if the system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. A public water system is either a “community water system” or a “non–community water system”.
(b) Systems include the following:
1. Any collection, treatment, storage, and distribution facilities under control of the operator of the system and used primarily in connection with the system, and
2. Any collection or pretreatment storage facilities not under the system’s control which are used primarily in connection with the system.
(c) The term does not include any ‘‘special irrigation district.’’ atmosphere and subject to surface runoff.

NR 809.04(4) “Community water system” means a public water system which serves at least 15 service connections used by year–round residents or regularly serves at least 25 year–round residents. Any public water system serving 7 or more homes, 10 or more mobile homes, 10 or more apartment units, or 10 or more condominium units shall be considered a community water system unless information is available to indicate that 25 year–round residents will not be served.

NR 811.02(16) “Municipal water system” means a community water system owned by a city, village, county, town, town sanitary district, utility district, public inland lake and rehabilitation district, municipal water district or a federal, state, county or municipal owned institution for congregate care or correction, or a privately owned water utility serving the foregoing.

NR 811.02(19) “Other–than–municipal water system” means a community water system that is not a municipal water system.

NR 809.04(47) “Noncommunity water system” means a public water system that is not a community water system. A noncommunity water system is either a nontransient, noncommunity water system or a transient noncommunity water system.

NR 809.04 (78) “Transient noncommunity water system” means a noncommunity water system that serves at least 25 people at least 60 days of the year. Examples of transient noncommunity water systems include those serving taverns, motels, restaurants, churches, campgrounds and parks.

NR 809.04(48) “Nontransient noncommunity water system” means a noncommunity water system that regularly serves at least 25 of the same persons over 6 months per year. Examples of nontransient noncommunity water systems include those serving schools, day care centers and factories.

The classification of a public water system is important because it determines the level of regulation that a system must follow. In general, community water systems and nontransient noncommunity water systems are subject to stricter requirements than transient noncommunity water systems. State and federal regulations define **“serve”** as having water available for people to drink, and not the number of people who actually drink the water on a daily basis. This definition is important because even if a supplier provides bottled water for drinking but has plumbing fixtures supplied by a private well, the water which comes out of those fixtures must meet drinking water standards.

DRINKING WATER STANDARDS

Drinking water standards are divided into two categories. Health related drinking water standards are called **Primary Drinking Water Standards** and non-health related aesthetic drinking water standards are called **Secondary Drinking Water Standards**.

Primary Drinking Water Standards

Primary Drinking Water Standards are those dealing with contaminants that are known to have an adverse effect on human health. Each regulated contaminant that EPA has determined poses a public health risk is assigned a ***Maximum Contaminant Level*** **(MCL)**. The maximum contaminant level or MCL is the maximum amount (concentration) of that particular contaminant in drinking water allowed by EPA. EPA has determined that water containing amounts of a contaminant lower than the MCL do not pose a significant risk to public health. Some MCLs apply to all water systems such as those for bacteria and nitrate. Other MCLs only apply to community (municipal and other-than-municipal) and nontransient noncommunity water systems such as the MCLs for volatile organic chemicals (**VOC**s) and synthetic organic chemicals (**SOC**s). Public water systems **must** provide water that meets all applicable MCLs for their specific water system type.

Secondary Drinking Water Standards

Secondary Drinking Water Standards deal with contaminants that affect the aesthetic quality of drinking water. These standards apply to such contaminants as iron, manganese, color, odor, and taste. As these contaminants have no known adverse health effects, public water systems are generally **NOT** required by state or federal drinking water regulations to meet these standards. The regulations do however give primacy agents authority to require corrective action when a secondary standard is exceeded and the resulting water quality is "*objectionable to an appreciable number of persons . .", or " detrimental to the public welfare . ."* .

Maximum Contaminant Level (MCL) and Maximum Contaminant Level Goal (MCLG)

Before setting a ***Maximum Contaminant Level*** or MCL for any health related drinking water contaminant, the SDWA requires EPA to set what are called ***Maximum Contaminant Level Goals*** (MCLGs). The MCLG for a contaminant is the level at which there is no known or anticipated adverse health effect to humans. This level is expected to provide complete protection of public health, thus, in many cases MCLGs are set at zero. MCLGs are generally significantly lower than MCLs because when EPA establishes an MCLG, they do **NOT** take into account cost, treatability, or detectability of a contaminant.

Realizing that, in some cases, it is not technologically or financially feasible to achieve the MCLG for all contaminants, EPA establishes ***MCLs*** for all regulated contaminants in drinking water. In doing so, they take into account such factors as health risk assessments, cost-benefit analysis, and ***Best Available Technology (BAT)***, in establishing acceptable levels. BAT refers to the technology available to detect and treat the contaminant of concern. EPA then sets the MCL as close to the MCLG as possible after taking all these factors into account. MCLs are the "drinking water standards" that all public water systems must meet. It is important to remember that MCLs are not set in stone. As new health effects data becomes available, MCLs are adjusted either up or down, depending on what the latest data shows.

Treatment Technique Requirement (TTR)

For some contaminants, establishing a specific MCL is either not possible or too costly to mandate. For such contaminants, EPA may also choose to require specific water treatment practices, called ***Treatment Technique Requirements,*** which, when implemented by the water system, would reasonably protect public health. Examples of TTRs are corrosion control for reduction of lead and copper, and filtration for removal of particulates in surface water.

VARIANCES AND CONDITIONAL WAIVERS

If a water system cannot comply with a MCL, the SDWA allows states to grant ***variances*** and ***conditional waivers*** (or exemptions) in certain situations.

Variances

A ***variance*** can be granted by the state if the water system has already installed BAT and if there is no unreasonable risk posed to the public health. In granting a variance, the DNR must establish a schedule for the system to come into compliance and any additional measures the water system must undertake during the period of the variance. Only the nitrate standard applied to noncommunity water systems and community water systems serving a nursing home, prison or mental health facility may be considered for a variance. Specific restrictions and requirements apply.

Conditional Waivers

The state may also consider granting a ***conditional waiver*** to a water system if the following three conditions exist:

- The water system is unable to comply due to compelling factors.
- No unreasonable risk to public health will exist as a result of the granting of the conditional waiver.
- The water system was in operation prior to January 1, 1989 or, if it is a newer system, there is no reasonable alternative drinking water source available.

In granting a conditional waiver, the state may require such conditions as increased monitoring, public notification, the installation of point-of-use treatment or filtration devices, or providing alternative water supplies to the customers. Conditional waivers are not generally granted for a period exceeding 3 years.

The difference between a variance and a conditional waiver

The main difference between a variance and a conditional waiver is that a water system does not have to install BAT before it applies for a conditional waiver. In either case, a variance or conditional waiver cannot be granted if there is an unreasonable risk to public health.

DNR NOTIFICATION

Although the regulations contain many different requirements for water systems to notify their DNR representative depending on the situation and the type of treatment the system uses, the most important notifications the water supplier must remember are:

As soon as possible, but no later than the end of the next business day when:

There is a waterborne disease outbreak potentially attributed to the water system.

The results of an unsafe water sample from any certified lab other than the State Lab of Hygiene.

Within 24-hours when:

When there is a failure to comply with any MCL, TTR, or monitoring requirement unless otherwise specified in drinking water codes.

Within 10-days of the end of a monitoring period :

For all results of any monitoring which occurred during the specified monitoring period (i.e. month, quarter, year, etc.).

For any monthly reports including the total monthly pumpage, static and pumping groundwater depth, and any other information on chemical addition (if added).

RECORD KEEPING REQUIREMENTS

Public water systems must retain copies of their records for certain lengths of time depending on the type of record. Monitoring records must contain certain information and must remain on the premises or at a convenient location near the premises.

Time Frame Requirements

The following is a general listing of the types of records and the length of time they must be kept:

Not less than 3 years:

Records of actions taken to correct violations.

Not less than 5 years:

Records of bacteriological analysis.

Records concerning a variance or conditional waiver.

Not less than 10 years:

Records of chemical analysis.

Copies of any written reports, summaries or correspondence relating to any sanitary surveys.

Not less than 12 years:

Records pertaining to lead & copper and corrosion control

Monitoring Records Requirements

Monitoring records must contain the following information:

- The name of the person who took the sample.
- The date, place and time of sampling.
- Identification of the sample (e.g., routine, check, raw water, entry point, etc.).
- The date of analysis.
- Laboratory and person responsible for performing analysis.
- The analytical method used.
- The results of the analysis.

PUBLIC NOTIFICATION

In addition to monitoring requirements, the federal government realizes that an important element of public safety is keeping the customer informed about the quality of their drinking water. Two regulations that were enacted to accomplish this goal are the ***Public Notification Rule*** and the ***Consumer Confidence Report***.

Consumer Confidence Report (CCR)

The ***Consumer Confidence Report*** is a report that community water systems (OTMs) must provide or make available to their customers annually. The report is an important public relations tool that shows customers the efforts made by the water supplier to provide safe water. It is designed to inform the customers of the quality of the water they are drinking. It must include information on:

- The water source.
- Steps the system is taking to protect the source water.
- The name and phone number of the person that customers may contact if they have questions about the report.
- The time, date, and location of any meetings held on a periodic basis that customers may attend.
- Definitions of the terms and abbreviations used in the report.
- The contaminants detected in the water (if any) and the level found.
- Information on the health effects of the contaminants detected in the water and where additional information is available.

- Any MCL and/or monitoring violations.

- Compliance with other drinking water regulations.

The report must be made available to every customer of the water system ***before July 1st of each year*** and must also be available in alternative languages if a significant number of the customers are non-English speaking.

Once the CCR has been completed and made available to the customers, the water system is required to complete a CCR Certification form detailing the efforts made to make the report available to the customers. Send the signed form and a copy of the CCR to the DNR.

Public Notification Rule

Whereas the CCR is designed to provide information to customers on an annual basis, the ***Public Notification Rule*** specifies how water suppliers must inform their customers in the event of a MCL violation or emergency situation. This rule went into effect in May 2000 and established specific language, actions, time frames, and methods that must be used to notify the public in these situations. The Public Notification Rule establishes ***Tiers*** for each contaminant and the type of situation that resulted in the violation.

Tier 1 Violation

A ***Tier 1*** violation requires notification of the public **within 24 hours**. Examples include violation of the MCL for total coliform, fecal or E. coli, nitrate and/or nitrite, chlorine dioxide, turbidity, TTR, waterborne disease outbreak, or other waterborne emergency as determined by the DNR.

Tier 2 Violation

A ***Tier 2*** violation requires notification of the public **within 30 days**. Examples include violation of a Maximum Residual Disinfectant Level, monitoring or testing procedure, failure to comply with the conditions of a variance or conditional waiver, or MCL and TTR requirement other than when a Tier 1 violation has occurred.

Tier 3 Violation

A ***Tier 3*** violation requires notification of the public **within 12 months**. Examples include a monitoring violation other than a Tier 1 or Tier 2; testing procedure violations other than a Tier 2; operation under a variance or conditional waiver; special notice for availability of unregulated contaminant monitoring data; or special notice for exceeding fluoride levels.

Tier Determination

In any of the above situations, the water supplier must notify the DNR as soon as possible for a determination of what tier applies to a given situation. The DNR will make that determination and work with you to provide the appropriate language and steps you must take to notify the public. "***When in doubt, call the DNR and find out.***"

VIOLATIONS

Violations of regulations for public drinking water systems can generally be placed in one of three categories. The categories are: ***water quality, water monitoring & reporting, and water system violations***. A listing of the regulations for public water systems in Wisconsin can be found in the Wisconsin Administrative Codes. The Code headings are listed at the end of this chapter and the complete codes are available at www.legis.state.wi.us/rsb/code/codtoc.html on the internet or by contacting the DNR.

Water Quality Violations
Water quality violations occur when the level of a contaminant(s) exceeds its MCL. The severity of the violation, and the resulting action that needs to be taken by the owner/operator, is determined by the risk posed to public health. Minimum required actions may include public notification and a time frame for compliance. If the violation poses a significant risk to public health, immediate notification, immediate treatment, and/or fines for non-compliance may apply.

Water Monitoring & Reporting Violations
Water monitoring and reporting violations occur when the owner/operator of a public water system fails to meet their monitoring and reporting requirements. Monitoring schedules for every public water system in Wisconsin are mailed to the well owner at the beginning of the year. These schedules list the contaminants that must be monitored at each well and the time frame in which the monitoring must occur. A list of certified laboratories is included with the monitoring schedule. It is the responsibility of the well owner to make sure that all samples are collected at the appropriate location, within the appropriate time frame, analyzed by a certified laboratory certified, and that the monitoring forms are completed, signed and submitted to the DNR within 10 days of the end of the specified monitoring period. Failure to complete <u>any</u> of these actions is a monitoring and reporting violation and may result in increased monitoring, public notification and/or fines. An owner/operator may also face substantial fines and/or penalties if he or she knowingly falsifies any monitoring or reporting data.

Water System Violations
Water system violations occur when a water system fails to meet code requirements for water system construction, operation, water pressure and flow. In most cases, violations of requirements for existing facilities are identified in sanitary surveys conducted by the area DNR Representative. Other violations occur when a water system owner fails to obtain the necessary DNR approval for facility upgrades, construction, and installation of water treatment. Violations of water system requirements will generally result in a compliance order listing the specific actions that must be taken and the time frame to complete the actions. Failure to take corrective action on a water system violation may result in substantial fines for the well owner/operator.

CAPACITY DEVELOPMENT

Capacity development is a relatively new DNR program that aims to help public water systems strengthen their ability to supply safe drinking water now and into the future. The program focuses on assisting system owners and operators, particularly small water systems, with improving their technical abilities, managerial skills, and financial resources to comply with the federal Safe Drinking Water Act (SDWA) requirements.

One of the goals of the Capacity Development Program is to help water systems improve operations and, most importantly, avoid contamination. The Capacity Development Program was authorized by the 1996 amendments to the SDWA, which established a strong new emphasis on preventing contamination.

Capacity, in this sense, does not mean just having enough safe water to drink. Rather, it means that a water system has the technical, managerial, and financial capability to ensure continuous delivery of safe drinking water to its customers now and into the future.

Capacity can be broken down into three, interrelated types. They are ***technical, managerial,*** and ***financial*** capacity. Each type is further defined as follows:

Technical Capacity
Technical capacity is the physical and operational ability of a water system to meet the SDWA requirements. It refers to the physical infrastructure of the water system, including source water adequacy, infrastructure adequacy (including well(s) and/or source intakes, treatment, storage, and distribution system), and the ability of water system personnel to implement the necessary technical knowledge to safely operate the system.

Managerial Capacity
Managerial capacity refers to the water system’s institutional and administrative capabilities. It refers to the management structure of the water system, including ownership accountability, hiring managing and training of water system staff and the overall water system organization.

Financial Capacity
Financial capacity refers to the financial resources of the water system. These resources include: revenue sufficiency (bill structures that take into account the need for future replacement of existing equipment), credit worthiness (the ability of the system owners to obtain and repay loans for needed capital improvements), and fiscal management (collection and management of sufficient revenues to safely operate and maintain the water system).

To assess these areas, the EPA required the DNR to create a Capacity Development Program. The program was finalized in August 2000. It is meant to be a proactive means of evaluating and assisting water systems before problems occur, instead of dealing with problems after-the-fact.

The first phase of Wisconsin's Capacity Development Program is to evaluate the "capacity" of each public water system. For new public water systems, the DNR evaluates system capacity prior to construction. For existing water systems, the DNR is using its inspection processes, namely sanitary surveys, to do this. Next, if capacity development problems are identified, the DNR uses different "tools" or activities to assist water systems. These tools will help public water systems comply with the SDWA requirements. Some of Wisconsin's capacity development tools include:

One-on-one technical assistance from state and local government staff: Staff from municipal, county, and state government offer assistance to water systems on a day-to-day basis to ensure that system owners and operators understand the regulations.

Operator Certification: The Operator Certification Program will help to ensure that water systems are run by appropriately trained and certified operators.

Informational materials and guidance: The DNR regularly prepares guidance documents to help owners and operators manager their public water system.

Technical assistance contractors: The DNR is working with the Wisconsin Rural Water Association (WRWA) to provide technical assistance to OTM and NTNC systems. The WRWA provides one-on-one assistance to water system operators, covering a variety of SDWA topics and issues.

CHAPTER REVIEW QUESTIONS ON DRINKING WATER REGULATION

1. Name of the act that sets standards, also known as MCLs, for drinking water quality?
2. What is the federal agency responsible for drinking water regulation?
3. What is the state agency responsible for drinking water regulations in Wisconsin?
4. What is the name of the authority given to states to enforce drinking water regulations in their state?
5. What is the name of the on-site inspections conducted by DNR representatives to make sure systems are in compliance with drinking water regulations?
6. Name the two main classes of public water systems.
7. What are the two sub-categories of community water systems?
8. What are the two sub-categories of non-community water systems?
9. What’s the main difference between a community water system and a non-community water system?
10. Name the two categories of drinking water standards.
11. What do the acronyms MCLG, MCL, TTR, and BAT stand for?
12. What is the difference between a variance and a conditional waiver?
13. What are the two regulations enacted that are aimed at the customer’s right to know about their water quality?
14. What is the name of the rankings established by the Public Notification Rule for severity of violations?
15. What are the three areas taken into account when assessing the capacity of a water system?

WISCONSIN ADMINISTRATIVE CODES FOR PUBLIC WATER SYSTEMS

Chapter NR 809- SAFE DRINKING WATER
NR 809.01- Purpose
NR 809.02- Department justification
NR 809.03- Applicability
NR 809.04- Definitions
NR 809.05- Coverage

Subchapter I- Maximum Contaminant Levels, Monitoring and Analytical Requirements
NR 809.09- Maximum contaminant level goals for primary contaminants
NR 809.10- Applicability of primary maximum contaminant levels to water sources
NR 809.11- Inorganic chemical maximum contaminant levels
NR 809.12- Inorganic chemical sampling and analytical requirements
NR 809.13- Sodium monitoring, reporting, and notification requirements
NR 809.14- Corrosivity monitoring, special characteristics
NR 809.20- Synthetic organic contaminant maximum contaminant levels and BATs
NR 809.21- Synthetic organic contaminant sampling and analytical requirements
NR 809.22- Total Trihalomethane maximum contaminant level
NR 809.23- Total Trihalomethane sampling and analytical requirements
NR 809.24- Volatile organic contaminant maximum contaminant and BATs
NR 809.25- Volatile organic contaminant sampling and requirements
NR 809.26- Special monitoring, reporting, and public notification for selected organic contaminants and sulfate
NR 809.30- Microbial contaminant maximum contaminant levels
NR 809.31- Microbial contaminant sampling and analytical requirements
NR 809.50- Radium-226, radium-228 and gross alpha particle radioactivity maximum contaminant levels
NR 809.51- Beta particle and photon radioactivity from man-made radionuclides maximum contaminant levels
NR 809.52- Analytical methods for radioactivity
NR 809.53- Radioactivity monitoring frequency for community water systems

Subchapter II- Control of Lead and Copper
NR 809. 541- General requirements
NR 809. 542- Applicability of corrosion control treatment steps for small, medium, and large-size water systems
NR 809.543- Description of corrosion control treatment requirements
NR 809.544- Source water treatment requirements
NR 809.545- Lead service line replacement requirements
NR 809.546- Public education and supplemental monitoring requirements
NR 809.547- Monitoring requirements for lead and copper in tap water
NR 809.548- Monitoring requirements for water quality parameters
NR 809.549- Monitoring requirements for lead and copper in source water
NR 809.55- Reporting requirements

Subchapter III- Maximum Contaminant Levels, Maximum Residual Disinfection Levels, Monitoring, Analytical Requirements, and Control of Disinfection Byproducts and Disinfection Residuals

NR 809.561- Maximum contaminant levels for disinfection byproducts, maximum residual disinfection levels and best available treatment
NR 809.562- General requirements
NR 809.563- Analytical requirements
NR 809.565- Monitoring requirements
NR 809.566- Compliance requirements
NR 809.567- Reporting and recordkeeping requirements
NR 809.569- Treatment technique for control of disinfection byproduct precursors

Subchapter IV- Secondary Chemical and Physical Standards and Monitoring Requirements

NR 809.60- Secondary inorganic chemical and physical standards
NR 809.61- Sampling and analytical requirements for secondary standards

Subchapter V- Miscellaneous Chemical Monitoring Requirements, Raw Surface Water Standards, Certified Laboratories, and Approved Methods for Safe Drinking Water Analysis

NR 809.70- General requirements
NR 809.705- Additional requirements for systems which chlorinate or fluoridate water
NR 809.71- Raw surface water standards
NR 809.72- Laboratories
NR 809.725- Approved analytical methods for safe drinking water analysis
NR 809.73- Monitoring of consecutive public water systems
NR 809.74- Sampling and analytical requirements for other chemicals

Subchapter VI- Filtration and Disinfection

NR 809.75- General requirements
NR 809.755- Criteria for avoiding filtration
NR 809.76- Filtration requirements
NR 809.765- Filtration sampling requirements
NR 809.77- Disinfection requirements
NR 809.775- Disinfection profiling and benchmarking
NR 809.78- Monitoring requirements

Subchapter VII- Reporting, Public Notification, Consumer Confidence Reports and Record Keeping

NR 809.80- Reporting requirements
NR 809.81- Public notification
NR 809.82- Record maintenance
NR 809.83- Consumer confidence reports
NR 809.833- Content of the reports
NR 809.835- Required additional health information

Subchapter IV- Source Development- Surface Water
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NR 811.26- Intakes
NR 811.27- Shore wells

Subchapter V- Pumping Stations
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NR 811.29- Buildings
NR 811.30- Number of pumping units
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NR 811.47- Iron and manganese removal
NR 811.48- Organics removal
NR 811.49- Ozonation
NR 811.50- Radionuclide removal
NR 811.51- Sequestration
NR 811.52- Softening
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Chapter 2
Source Water

SOURCE WATER

For many years, when people wanted water, they simply picked a spot and drilled, dug, or pounded a well into the ground with little thought other than getting enough water to suit their needs. Those days are gone. These days, when people are looking for water, as much consideration must be paid to the quality of the water, as the quantity. This chapter explains the water cycle, water sources, water quality, and its characteristics. It also explains the actions well owners can take to protect the quality of the water they already have.

THE HYDROLOGIC CYCLE

The hydrologic cycle is the continuous movement of water through the environment. Water undergoes physical, chemical, biological, and radiological changes due to different factors in the environment that affect its quality and characteristics.

Evaporation and Transpiration

Illustration 2-2 shows the hydrologic cycle. It starts with water entering the atmosphere through ***evaporation*** from surface water bodies such as ponds, lakes, rivers, and oceans. Evaporation is the changing of water from a liquid to a gaseous state called ***water vapor***. Water also enters the atmosphere through ***transpiration.*** As plants take up water through their root system, it moves through the plant and returns to the atmosphere through tiny pores in its leaves.

Condensation

As water vapor enters the atmosphere it changes from water vapor to ***water drops***. This process, caused by the cooling of water vapor, is called ***condensation***. A good example of condensation is the liquid that forms on the outside of a cold glass of water on a hot summer day. As condensation occurs in the atmosphere, clouds are formed. Clouds are made up entirely of tiny water drops or ice crystals.

Precipitation

As clouds absorb more and more water, they reach a point where they can hold no more and the water falls to the earth. This is called ***precipitation***. In warm temperatures, it falls as drizzle or rain. In cold temperatures, it falls as hail, sleet, or snow.

Infiltration, Runoff, and Percolation

Once water reaches the earth's surface, some of it is absorbed by the soil. The process of water moving into the soil is called ***infiltration***. Once water infiltrates into the soil, some is taken up by plant roots and re-enters the atmosphere through transpiration. Some of the water moves further down through the soil. This is called ***percolation***. Some may return to the surface through the ***capillary action*** of the soil. Capillary action is the movement of water through tiny pores in soil due to the molecular attraction between the water and the soil. An example of capillary action is what occurs when you put a cloth partially into a glass of water. Through capillary action, the water moves up the cloth, above the water level in the glass.

When soil can no longer hold any more water, it becomes ***saturated***. If more precipitation falls, some of the water begins to flow across the ground. This is called ***runoff***. Runoff flows into creeks, streams, rivers, and lakes and eventually re-enters the water cycle through evaporation.

Aquifers and Groundwater

The water that infiltrates into and percolates down through the soil and rock eventually reaches a saturated zone called the ***water table***. Below the water table is an ***aquifer***. An aquifer is a water-bearing soil or rock formation below the earth's surface. The water contained in the aquifer is ***groundwater***. There can be more than one aquifer below the surface in any one location. Aquifers fall into two broad categories, ***unconfined*** and ***confined***.

Unconfined and Confined Aquifers

An ***unconfined aquifer*** is located in a permeable formation where the water table is free to rise and fall, depending on factors such as the amount of rainfall and recharge. ***Confined aquifers*** are situated below an impermeable layer (confining layer) such as shale or clay. If an impermeable layer exists above the surrounding water table, a ***perched*** aquifer may form.

Consolidated and Unconsolidated Formations

Unconfined aquifers are often made up of sand and gravel formations. These formations are called ***unconsolidated*** because they are made up of loose materials that are not cemented together. Most unconsolidated formations are made up of glacial or river deposits formed millions of years ago. A ***consolidated*** formation consists of firm, coherent rock, such as sandstone, granite, dolomite, or limestone. Most consolidated formations were deposited hundreds of millions of years ago.

Springs and Artesian Wells

If a confined aquifer gets its water from a source at a higher elevation, it may be under pressure. If a well is cased through the confining layer, water in the well may rise above the aquifer - a further indication that it's under pressure. A well placed into this aquifer is called an ***artesian*** well. If water flows out of the well without being pumped, it is called a ***flowing artesian*** well.

Springs may form when an impermeable layer such as clay intersects a hillside. As water percolates down through the soil and intercepts the clay layer, the water flows along the top of the clay layer until it discharges on a hillside. Springs may also form when water-bearing fractured rock intersects a hillside.

Water Movement in Aquifers
Gravity controls the movement of groundwater in aquifers. Like surface water, groundwater flows downhill. The natural movement of groundwater is from a point of high elevation (uplands) to a low one (lowlands), where it eventually discharges to a lake, stream, wetland, or spring. Near the coast, groundwater may discharge to the ocean.

Geology controls the rate of groundwater movement. In sand and gravel aquifers, groundwater may move hundreds of feet per year. In an aquifer made up primarily of silt and clay, groundwater moves only a few inches per year. Most groundwater moves a few feet per year. There are many factors that affect how groundwater moves including the permeability of the formation, fractures in the rock, the size and location of the recharge areas, and wells pumping from the aquifer. ***Permeability*** refers to the ability of rock or soil to transmit water. It is possible for groundwater to move at different speeds at different depths in the same aquifer.

DRINKING WATER SOURCES

Water exists in the environment in different forms and locations. The ***source*** of drinking water refers to where it's taken from. There are three main sources of drinking water in Wisconsin: surface water, groundwater, and groundwater-under-the-influence of surface water.

Surface Water
Water that is obtained from lakes, reservoirs, and rivers is called ***surface water***. Surface waters are very susceptible to contamination. You name it - manure, gasoline, pesticides, fertilizers, industrial chemicals, bacteria, air pollution – it can enter surface waters. Because of their high susceptibility to contaminants, surface water sources must meet strict monitoring and treatment requirements.

While there are relatively few surface water systems in the world, they provide more water to more people than any other type of system. They are typically used by large cities that need a large volume of water to meet their needs.

Groundwater
The water that is obtained from aquifers is called groundwater. Groundwater is generally less susceptible to contamination than surface water. Groundwater's susceptibility to contamination depends on the type and thickness of soil and rock layers, depth to the groundwater, and the type of contaminants. Some soils are very good at filtering out contaminants. Others are not. The central sands area and karst features of Wisconsin are very susceptible to groundwater contamination. In contrast, areas with thick, rich soil and a good depth to groundwater are generally less susceptible to contamination. In some areas of the state, groundwater may become contaminated with naturally occurring

minerals in the soil and rock such as arsenic, lead, radium, radon gas and uranium. Groundwater systems generally have less restrictive monitoring and treatment requirements than surface water systems.

Groundwater Under the Influence of Surface Water
Water that is obtained from an aquifer that may be intermixed with surface water is called "groundwater under the influence of surface water". This situation may occur when a well is placed next to a lake or river. As the well is pumped, some of the water from the lake or river enters the groundwater, which, in turn, can reach the well. In other words, the groundwater has a connection to the surface water. This connection makes the groundwater susceptible to the same types of contaminants as the surface water. Groundwater under the influence of surface water is covered by the same regulations as surface water systems.

GROUNDWATER SOURCES IN WISCONSIN

The state of Wisconsin has a varied geology, which allows groundwater to exist in a variety of formations and aquifers (see illustration 2-3). In Wisconsin, there are four principal aquifers: the sand and gravel aquifer, the eastern dolomite aquifer, the sandstone and dolomite aquifer, and the crystalline bedrock aquifer. These aquifers were formed by a variety of geologic processes including igneous intrusions, ancient oceans, and more recently, glaciers that covered 2/3 of the state during the Ice Age (see table 2-1).

The Sand and Gravel Aquifer
The sand and gravel aquifer covers most of the state, except for parts of southwest Wisconsin. Glaciers did not cover the southwestern portion of the state. This part of the state is known as the "Driftless Area". In Wisconsin, many sand and gravel formations are the result of the glacial movement and materials that were deposited as the ice melted. These shallow aquifers can be more than 300 feet thick in places and provide large volumes of groundwater. Because they are at or near the land surface and have little filtering capacity, they may be very susceptible to contamination.

The Eastern Dolomite Aquifer
The eastern dolomite aquifer, formed around 400 million years ago, is a narrow strip of Niagara dolomite over Maquoketa shale that exists along the easternmost part of the state, from Door County to the Illinois border. In some areas, the dolomite bedrock occurs at or near the surface leaving the shallow groundwater especially susceptible to contaminants. As dolomite is similar to limestone, groundwater resides in the interconnecting cracks and crevasses. Thus, the amount of water that can be obtained from a well is largely dependent on the cracks and crevasses it intersects. The Maquoketa shale is an impermeable rock layer formed from clay. It serves as a barrier between the eastern dolomite aquifer and the sandstone and dolomite aquifer below it.

The Sandstone and Dolomite Aquifer
The sandstone and dolomite aquifer formed from 425 to 600 million years ago. It covers most of the state, except in the northcentral Wisconsin. Along the eastern edge of the state, this aquifer exists below the Maquoketa shale. Throughout the rest of the state, it lies below the sand and gravel formations. As opposed to dolomite, the sandstone in this formation can produce substantial amounts of water, making it the principal bedrock aquifer for wells in the southern and western areas of the state.

The Crystalline Bedrock Aquifer
The crystalline bedrock aquifer formed from 600 million to 4 billion years ago. It is made up of a granite-type crystalline structure that underlies the other aquifers throughout the entire state. As in the dolomite formations, water in the crystalline bedrock is contained mostly in cracks and crevasses.

WATER QUALITY AND CHARACTERISTICS

The quality and characteristics of water are influenced by many factors including where it comes from and what it's exposed to as it travels through the hydrologic cycle. Water quality and characteristics are important to consider when choosing a water source. The four general categories of water characteristics are ***physical***, ***chemical***, ***biological,*** and ***radiological***.

PHYSICAL CHARACTERISTICS

Water ***temperature*** will dictate how it tastes, how easily it dissolves things, and whether it's effective for other uses such as cooling. Generally, surface water sources are warmer than groundwater sources.

Turbidity is the cloudiness caused by matter or particles suspended in the water. This matter may include natural organic material, which is of aesthetic concern, but it may also include algae, bacteria, or microorganisms, which can cause serious health problems. Usually, the turbidity of groundwater is near zero due to the filtering characteristics of soil.

The ***color*** of water can be an important characteristic. Although color may be present in groundwater due to certain minerals or natural organic compounds, it is primarily of concern for surface water sources. Color is typically caused by the decomposition of organic materials such as leaves and plant remains.

The ***taste*** and ***odor*** of water can be caused by chemicals, minerals, decaying matter, or dissolved gases. The most common cause of odor in drinking water is the presence of hydrogen sulfide, iron, or sulphur-reducing bacteria. In a distribution system, the corrosion of pipe materials can also cause taste and odor. Even though taste and odor are more of an aesthetic concern than a health related one, their presence may be indicative of other contaminants that may be harmful to public health.

CHEMICAL CHARACTERISTICS

The chemical characteristics of water can be broken down into two main groups: organic and inorganic. Organic chemicals are carbon based, whereas inorganic chemicals are not.

Organic

Organic chemical characteristics in water come from the breakdown of naturally occurring materials, introduction of contaminants from human activities, and the reactions that occur during water treatment and distribution. The most common organic chemicals come from the breakdown of natural materials such as leaves and plants, aquatic decomposition, and other natural by-products. However, solvents, pesticides, herbicides and other commercial and industrial products are becoming more common in drinking water.

Inorganic

Inorganic chemical characteristics include such things as pH, hardness, dissolved oxygen, dissolved solids, and electrical conductivity.

pH

The ***pH*** of water is the level of its acidity or alkalinity. The pH scale is a numerical scale from 0 to 14. A pH of 7 is considered neutral. Generally, anything below 7 is considered acidic, and anything above 7 is considered alkaline. However, there are exceptions (see Driscoll, 1986). Acidic water has a tendency to corrode materials it comes into contact with. Conversely, alkaline water has a tendency to leave a scale buildup on the inside of plumbing fixtures.

Hardness

Hard water contains high amounts of calcium and magnesium ions. Hard water can be a problem because it requires more soap when washing and can lead to a buildup of calcium and magnesium on the inside of plumbing. This is especially true when hard water is heated, such as in a water heater. However, this scale buildup can have the beneficial affect of preventing lead and copper from leaching from plumbing fixtures into the water.

Dissolved Oxygen

Dissolved oxygen or DO is a common dissolved gas in water. Dissolved oxygen can enter the water from the air (aeration), by plants (photosynthesis), or introduced as part of a treatment process such as “air stripping”. High levels of dissolved oxygen in water can cause it to be corrosive, especially to metallic surfaces.

Dissolved Solids
Water is sometimes referred to as the "universal solvent" because it tends to dissolve minerals that it comes into contact with. Therefore, it may contain a variety of dissolved minerals. Some of these minerals such as arsenic, barium, lead, mercury and silver, can adversely affect human health, while others affect the aesthetic quality of water such as iron and manganese. The sum of minerals dissolved in water is referred to as ***Total Dissolved Solids*** or TDS. Water with higher levels of dissolved minerals can cause problems with taste, odor, hardness, corrosion, and buildup. It can also cause problems when used in manufacturing processes.

Electrical Conductivity
The ***electrical conductivity*** of water is its ability to conduct an electric current. Ions dissolved in the water cause electric current to flow. One way to determine the level of TDS in water is to measure its electrical conductivity. Water with less dissolved solids will conduct less electricity than water with high levels of dissolved solids.

BIOLOGICAL CHARACTERISTICS

Perhaps for drinking water the most important water characteristic is its biological quality. Microbial contaminants such as bacteria, viruses, and microscopic organisms pose the greatest health risk challenge for water system owners and operators. Mild to moderate illness lasting days to weeks can result from exposure to microbial pathogens. More serious health problems, even death, can result when people with weakened immune systems are exposed to pathogens. Microbial pathogens are present in human and animal feces, which can, in turn, contaminate drinking water.

Bacteria
Bacteria found in water, such as coliform, salmonella, Legionella, and E. coli, are generally attributed to human and animal wastes. The total coliform group of bacteria are found nearly everywhere in the environment, except in clean water. Some specific types of coliform bacteria are also associated with the digestive tracts of humans and many animals. While most forms of coliform bacteria are harmless, their presence in drinking water can indicate that either the water source or the distribution system has been contaminated by an external source. As such, the presence of total coliform in drinking water may be an indication that other more harmful bacteria, such as E. coli, are present.

Fortunately, most forms of bacteria found in drinking water can be treated effectively with modern disinfection methods such as chlorine. However, when a system finds coliforms in its drinking water, it may indicate that water treatment system is not working properly. In these cases, disinfection equipment repair, flushing or upgrading the distribution system, and enacting a source water protection program may be necessary.

Viruses
Viral infection of drinking water supplies is another major concern in the protection of public health. Examples of waterborne viruses include enterovirus, rotovirus, and

hepatitis. As with bacteria, the presence of viruses in drinking water may be associated with human wastes. If viruses are detected in drinking water, immediate steps must be taken to rectify the problem.

Microscopic Animals
Although most disease causing microscopic animals, or ***protozoans***, are not naturally found in water, they can survive in water for a period of time. Examples of such animals include *Giardia* and *Cryptosporidium*. Their presence is also attributable to human and animal wastes, but unlike most bacteria and viruses, they can be particularly difficult to detect and treat in drinking water. That's because they are resistant to chlorine and can easily pass through inefficient filtration devices. Proper disinfection and/or filtration, system maintenance, and regular system upgrades are essential to protecting human health from these pathogens.

RADIOLOGICAL CHARACTERISTICS

Although the presence of radiological elements, or ***radionuclides***, in drinking water may be attributed to human activities, they are most often a result of dissolution of naturally occurring radioactive elements in rock formations such as granites. Examples of radionuclides found in drinking water include radium 226, radium 228, uranium, and radon. When consumed at high levels, these radioactive contaminants are known to cause cancer in humans.

SOURCE WATER PROTECTION

For many years, people assumed that there is an unending supply of clean, safe water. However, we now know that many human activities can contaminate groundwater. That's why it's so important to prevent contamination whenever possible. Fortunately, there are many things water suppliers can do to protect the quality and quantity of their source water.

Water Conservation
One way to protect the quality and quantity of water is to limit the amount that is used. This is called ***water conservation***. Although the earth contains adequate resources of water, it is disproportionately distributed. In some areas of the state, the amount of water available is decreasing at an alarming rate. As these supplies dwindle, either new wells must be drilled or existing ones drilled deeper. If you drill deeper, natural contaminants may be encountered. If you pump too much water from existing wells, pesticides, gasoline or other contaminants may be drawn in. Any way you look at it, water conservation is a wise investment.

There are many ways to conserve water such as promoting the use of low-flow faucets, toilets, and showerheads. Industries can also be encouraged to recycle and reuse water in their processes. Perhaps the most effective means of promoting water conservation is public education. As customers become aware of the potential health risks of contaminated water and the high costs of treatment, they will learn to use water wisely and protect it as a valuable resource.

Wellhead Protection
One way to protect the quality of water around your well is to limit the amount of contaminants that enter its recharge area. Although not currently required for Other-Than-Municipal or Nontransient Noncommunity wells, a Wellhead Protection Plan identifies the recharge area for a well and potential contaminant sources within it. The Wellhead Protection Plan establishes a plan to protect the recharge area and a public education program to inform people about activities that may contaminate the groundwater.

Source Water Assessments and ***Vulnerability Assessments*** identify potential land-use activities near your well that could contaminate groundwater. Once these are identified, ***Wellhead Protection Plans*** can be adopted which restrict such activities in recharge areas.

Well Abandonment
Wells are a direct conduit to the groundwater and aquifers. It is important to properly abandoned wells that are no longer in use, are contaminated, or don’t comply with existing codes.

Wisconsin’s well abandonment requirements are listed in section NR 812.26 of the Wisconsin Administrative Code. This code outlines the requirements for permanently abandoning wells. An owner should abandon a well if any of the following conditions exist:

- The well is contaminated with biological, viral, or parasitic pathogens and 3 attempts at disinfection fail to eliminate the problem.

- The well is contaminated with a substance in exceedence of a drinking water standard(s).

- The well poses a hazard to health or safety.

- The well does not conform to construction or location requirements.

- The well was not constructed by the owner or a licensed well driller.

- The well has been out of service for 3 or more years.

- The well has been temporarily abandoned for 2 or more years.

Temporary Abandonment
- Wells may be temporarily abandoned if they will be used in the near future.

- The well casing pipe shall remain in place unless ordered removed by the DNR. Chapter NR812 provides specific information about how a well must be abandoned, including:

- All debris, pumps, piping and any other obstruction must be removed prior to abandonment.

- For wells larger than 2 ½ inches, if a sealing material, other than bentonite chips, is used, it must be installed from the bottom up by use of a conductor pipe or bailer submerged in the sealing material at all times.

- The sealing material must be approved by the DNR such as neat cement grout, concrete grout, or bentonite chips.

- An abandonment report must be filed with the DNR within 30 days.

REVIEW QUESTIONS FOR SOURCE WATER

1. What is the name of the cycle that explains how water moves through the environment?

2. What is the name of the process by which water changes from a liquid to a gaseous state?

3. Name the process where water moves into and down through the soil.

4. What is the difference between a permeable formation and an impermeable layer?

5. What factors can affect how water moves through an aquifer?

6. What is the difference between a confined aquifer and an unconfined aquifer?

7. What is the difference between a consolidated formation and an unconsolidated formation?

8. Name the three sources of drinking water.

9. Name the four main aquifers in Wisconsin.

10. Name the four main categories of water characteristics.

11. What are the four main physical characteristics of water?

12. What is the most common source of organic chemicals in water?

13. What chemical characteristics of water can affect its corrosivity?

14. What two biological contaminants in water are associated with human and/or animal wastes?

15. Name two protozoans that can be found in drinking water.

16. What is the most common health affect associated with radiological contaminants in drinking water?

17. Name four actions that an owner/operator can take to protect the quality of their water source.

Chapter 3
Wells

TYPES OF WELLS

Virtually every small water system in Wisconsin obtains their water from a well. Wells are defined as any opening into the ground to obtain water where the depth of the opening is greater than the largest surface dimension. Depending on the depth to groundwater, the amount of water needed, and the water quality, wells can range from a few feet to thousands of feet deep. Most public wells in Wisconsin are 100 feet to 500 feet deep, depending on the formation used to obtain water. The methods used for constructing wells are digging, driving, and drilling.

Dug Wells
Dug wells are typically constructed in areas with very high groundwater levels (i.e. very near the ground surface. See illustration 3-1). They utilize a constructed box or circular structure, which allows water to seep into the well where it can then be pumped out for use. These wells were widely used before modern drilling equipment was invented. An example of a common dug well is the “Wishing Well” with the rope and bucket attached to a hand crank. These wells often pose a safety hazard and are prone to contamination. The DNR discourages their construction and use, hence they are no longer very common in Wisconsin. Dug wells may not be constructed without written approval from the DNR.

Driven Wells
Driven wells are constructed by driving a pipe with a point and screen into the ground (see illustration 3-2). Because they are often installed in areas with sandy soils, they are also called “sand-point” wells. Due to the limitations in how deep they can be driven, they are generally used in areas that have a shallow groundwater level. In certain areas of Wisconsin, driven wells are still common for single-family residential wells. They are not allowed for use by public water systems and are only allowed for private residences and transient non-community system wells.

Drilled Wells
Almost all modern wells constructed for public use are drilled wells (see illustration 3-3 and 3-4). They can be drilled using many different methods, but in Wisconsin the two most common methods are the cable-tool (percussion) method and the rotary-drilling method.

Cable-Tool (Percussion) Method
The cable-tool method uses a bit which pounds its way into the ground crushing the soil material and rock it encounters. Periodically, the bit is removed and the crushed material is removed from the drill hole using a bailer. The bailer is a section of pipe, smaller in

diameter than the casing, with a check valve at the bottom. As the bailer is lowered, the check valve is open and it fills with the crushed material. As it is lifted, the check valve closes and the material is lifted to the surface and discarded.

Rotary Drilling Method

The rotary drilling method uses a spinning drill bit that is lowered into the ground. Water or air is pumped down, either through the outside or inside of the drill bit. It cools the bit and carries the drilled materials to the surface. When constructing wells through loose materials or soft bedrock, clay can be mixed with the drilling water to provide a "slurry" that removes the drill cuttings and keeps the drillhole open and the drill bit lubricated.

Well Casing

In both the cable-tool and rotary drilling methods, steel casing is installed to keep the hole from caving in (see illustrations 3-3 and 3-4). The casing lengths are welded or threaded and coupled together to form a continuous casing from the surface to the sand and gravel formation or bedrock formation below. Casing not only serves to keep the well-hole open, but it also prevents contamination from entering the well and groundwater. It helps ensure that the well will produce bacteriologically and chemically safe water. In Wisconsin, casing pipe depth requirements are based on whether the well is constructed in a sand and gravel formation or bedrock. Because the top layers of some rock formations can be somewhat porous, the casing is installed into the rock formation to a depth where solid bedrock is encountered.

Grout

Openings or voids may be created around the casing during the drilling process (see illustrations 3-3 and 3-4). These voids, or annular spaces, are filled by the driller with a type of cement called "grout". The grout acts as a seal to prevent contamination from moving down the casing to groundwater and also acts to stabilize the formation and protect the exterior of the casing from corrosion. For wells drilled into bedrock formations, the grout is installed from the surface to the bottom of the casing, whether it is at the top of the bedrock formation or deep into it.

Gravel-Pack Wells

In wells where soft or very fine-grained sands are encountered, a gravel pack is used to prevent the sand from entering the well. For a gravel-pack well, a larger borehole is drilled and a screen is attached to the casing. A screen is a filtering device that allows water to enter a well, but not sediment. In a gravel-pack well, small stone or gravel is installed around the screen and casing. This gravel allows water to freely enter the well during pumping, but it prevents the formation sand from entering the well.

Vents

All wells must have vents to allow for the displacement of air during the pump starting and stopping cycles. Without a vent, a vacuum could be created which prevents the well from pumping water. Vents consist of a pipe installed in the well casing or well cap or seal to allow for the displacement of air between the casing and the pump column. When the pump starts, air is drawn into the casing as the water level drops. Conversely, when the pump shuts off, air is expelled through the vents as the water level returns to the static water level. All vents must have screens to prevent any solid material, vermin, and insects from entering the well.

Sources of Contamination
Because a well is a direct conduit from the surface to the groundwater below, care must be taken to prevent contamination from entering the well. It is important to place wells in high areas, out of floodways and storm water runoff areas, to prevent surface water from entering the well. Further, minimum separating distances must be kept between the well and other potential sources of contamination such as septic tanks, animal yards, buried petroleum tanks, etc. It is also important to make sure that the well cap or seal is in place and the vent pipe is screened to prevent access by vermin and insects. Well owners should inspect them frequently.

WELL PUMPS

There are two basic types of well pumps: the vertical turbine pump and the submersible pump.

The vertical turbine pump has a motor above ground connected by a shaft to the pump below. The pump itself has a series of impellers called bowl-assemblies which, when turned, push the water to the surface through a pump column (see illustration 3-7).

The submersible pump has a motor and pump assembly attached at the bottom of the column, with an electric wire running from the surface to the motor below (see illustration 3-8). This arrangement precludes the need for shafts to turn the impellers.

Static Water Level
The top of the water level in the well while the pump is not running is called the static water level (see illustration 3-5). In most cases, the static water level rarely fluctuates much over time as the aquifer is recharged through the hydrologic water cycle. But in some cases, due to excess pumpage from the aquifer over time, the static water level lowers as the aquifer becomes depleted.

Pumping Water Level
The top of the water level in the well while the pump is running is called the pumping water level (see illustration 3-6). This level is important because it is an indicator of the ability of the aquifer to supply water to the well.

Drawdown
The difference between the static water level and the pumping water level is known as the drawdown of the well (see illustration 3-6). Drawdown is determined by the ability of the aquifer to replace the amount of water that is being pumped from the well. If there is an abundance of water in an aquifer and the water can move freely to the well, the drawdown will be fairly low, typical of sand and gravel formations. Conversely, if the

water cannot move through the formation quickly enough to replace the water being pumped, the drawdown can be quite high.

Well Yield and Specific Capacity

Well yield and specific capacity are two terms that refer to the measurement of the amount of water a well can produce. Well yield is generally expressed in gallons per minute (gpm). Specific capacity is the rate of water that discharges from a well per unit of drawdown (usually feet). It is determined by dividing the well yield by the drawdown and is usually expressed in gallons per minute per foot (gpm/ft). For example, if a well pumps 100 gpm and it has a drawdown of 30 feet, its specific capacity at that flow rate is 3.33 gpm/ft. By tracking the specific capacity of a well over time, an operator can identify well and aquifer performance problems.

Cone of Depression

As water is pumped from the well, a depression in the water table forms in the shape of an inverted cone called the cone of depression (see illustration 3-6). If the drawdown is low, the cone of depression may only extend for a short distance away from the well. Conversely, if the drawdown is high, the cone of depression can extend for quite a ways out from the well, in some cases for hundreds of feet. The cone will continue to enlarge until the rate of groundwater flow or recharge equals the pumping rate, or sufficient leakage occurs between formations to equal the pumping rate, or the cone intercepts a surface water body (lake, stream, etc), or some combination of these occur.

WELL CODE REQUIREMENTS

Wisconsin has strict code requirements for the placement, construction, and operation of public wells. These requirements are found in Chapters NR 811 and 812 of the Wisconsin Administrative Code and are enforced by the DNR. Different wells have specific requirements based on their type, size, and use. A list of the general well construction requirements are provided below. However, this list is not all-inclusive.

General Requirements

- DNR approval is required for the construction, reconstruction, or operation of a public water system well.

- The location of a proposed well must comply with the minimum separation distances to all contamination sources (See “Well Placement” or NR 812.08).

- Wells must be planned and constructed so that they produce an adequate supply of safe water and are adapted to the geographic and geologic conditions of the site.

- Wells must meet DNR plumbness and alignment requirements.

- The top of the well casing must be at least 2 feet above the regional flood level and at least 12 inches above the ground surface.

- DNR approval must be obtained for any below ground style discharge.

- Well casing must meet DNR thickness and material requirements.

- New wells shall be sealed with an approved weather and vermin-proof well cap or seal.

- Wells shall be provided with a screened downward facing well vent.

- Grout must be at least 1½ inches thick around the entire casing and any casing couplings.

- A written well construction report must be submitted to the DNR within 30 days of completion of the well.

- The well must be constructed by a licensed well driller.

WELL CONSTRUCTION APPLICATION

To construct a well in Wisconsin, an application must be submitted to the DNR providing the following information:

- The purpose of the well.

- The name and address of the individual, corporation, partnership or sanitary district that owns the property on which the well will be constructed.

- The name and address of the owner and/or operator of the well system.

- A written description and map of the entire property on which the well will be constructed.

- On the property map, the location of the proposed well and any other existing wells.

- On the property map, the locations of any nearby wells on other property.

- On the property map, any wetlands within 300 feet of the proposed well.

- Any information on any other existing wells on the property.

- Details on the proposed well including:

- Well depth
- Depth, material, and thickness of casing
- Type, material, and length of screen
- Geological formation
- Grouting material
- Method used to construct the well
- Name of well driller
- Location of the sampling faucet
- Distance from the well to any contamination source
- Type and capacity of the pump, and how it's connected to the discharge piping
- Type and design of the well cap
- Pump discharge-piping information including check and shut-off valves & air relief

WELL SITING

Due to the numerous factors that must be taken into account when choosing a site for a new well, it is important to utilize every available resource at your disposal. Fortunately, information is available from a variety of sources.

Well logs from other nearby wells are a valuable source of information on the underground geology of the area. These logs are required by Wisconsin Administrative code for any new well and must show the underground formations encountered and the depths at which they were found.

Area well drillers are a valuable source of information. They are not only familiar with local geology, but also the quantity and quality of the water from the wells they have drilled.

Local, state, and federal natural resource agencies can provide valuable information on an area's geology, known sources of contamination, and regional water quality.

Water quality sampling results from testing done at wells in the area can provide valuable information on water quality at different depths of a formation. This sampling is required for all community and noncommunity wells.

WELL PLACEMENT

In general, a well should be located so that its surroundings can be kept in a sanitary condition. If possible, it should also be located at the highest point on the property so that it is protected from flooding and other contaminant sources. Wells should not be located downstream of any contamination source. They should be as far away from sources of contamination as possible.

Table 3-1 shows the minimum separation distances for Other-Than-Municipal and Nontransient Noncommunity wells from some common contamination sources. (Note - In special circumstances, the DNR may grant a variance to minimum separation requirements).

SPECIAL REQUIREMENTS

Chapter NR812 of the Wisconsin Administrative Code contains special requirements for wells constructed in different formations. These requirements are as follows:

Requirements for Unconsolidated Formation Wells

- Casing diameter shall be a minimum of 4 inches.
- A minimum casing depth of 60 feet below the surface or 20 feet below the static water level, whichever is greater.
- The cased and grouted depth for screened wells shall extend, where practical, to at least 5 feet below the normal pumping level and to within 5 feet of the top of the screen unless the grout depth is at least 60 feet.
- Continuous chlorination and adequate contact time for disinfection shall be required except in cases where the proposed well construction provides sufficient protection as determined by the DNR.
- An adequate screen shall be provided where necessary to prevent sand pumping.
- The pump intake shall be set at least 5 feet above the bottom of the well casing and shall be set so that the pump does not break suction under normal conditions.
- If the well is gravel packed, the gravel shall be acid resistant and free of foreign material, properly sized, washed and disinfected prior to or during placement.
- A sand or bentonite seal to prevent leakage of grout into the gravel pack shall be provided. The seal shall be no more than 2 feet thick.
- No materials may be installed in a well having a lead content greater than 8% by weight.

Requirements for Gravel-Pack Wells

- Gravel or coarse sand used for gravel packing shall be uniformly graded, well rounded, washed and sterilized.
- Screens placed in gravel packed wells shall have centering guides on the top and bottom to ensure an even gravel pack.

- Screens must be of an approved design and material.

Requirements for Dug Wells

- Dug wells and springs shall be approved only when it is not feasible to construct a drilled well.

- Plans for a dug well shall include facilities for the continuous chlorination of the water and adequate contact time before the water reaches consumers.

- Dug wells shall be covered by a concrete cover which terminates no less than 12 inches above the ground surface.

- The area around the well shall be under the control of the supplier.

- The curbing wall shall be circular concrete or steel and watertight to a depth no less than 25 feet below the established ground surface.

Requirements for Sandstone Wells

- The minimum depth of the grouted casing shall be 60 feet. The casing shall be installed to a depth 10 feet below the anticipated pumping water level, except in cases where the DNR determines this is not necessary.

- When sandstone is overlain by limestone or shale formations, the grouted casing shall be installed 15 feet into the firm sandstone.

- Where the depth of unconsolidated material is more than 60 feet the protective casing shall be seated in firm sandstone where the sandstone is the upper rock formation.

Requirements for Limestone Wells

- When an acceptable sandstone formation can be utilized, construction of limestone wells should be avoided.

- Continuous chlorination and detention time shall be required as a safe guard for limestone wells when determined necessary by the DNR.

- Where the depth of unconsolidated material is more than 60 feet and only 60 feet of grouted casing is required, the casing shall be seated in firm limestone.

REVIEW QUESTIONS FOR WELLS

1. What's the most common type of water source for water systems in Wisconsin?

2. Name the three most common methods of constructing a well.

3. What are the two most common methods of constructing a drilled well?

4. What is the name of the steel pipe that forms the outside of the well hole?

5. What is used to fill in voids around the casing of a well?

6. What must be installed on the bottom of the casing in a gravel-pack well?

7. What must be installed in a well to allow air to displace the water that is pumped out?

8. Name the two types of well pumps.

9. What is the term for the water level in a well when the pump is not running?

10. What is the term for the water level in a well when the pump is running?

11. What is the term for the indentation in the water table that forms around a well as its pump is running?

12. What are some of the items which must be included on a new well construction application?

13. Name a few of the informational resources available to someone constructing a new well.

Chapter 4
Contaminants

DRINKING WATER CONTAMINANTS AND MONITORING

The following is a description of the contaminant sources, monitoring requirements, sampling procedures, health effects, and treatment options for the categories of contaminants regulated under the Safe Drinking Water Act. For the specific contaminants in each category, see the table at the end of this chapter.

BACTERIOLOGICAL

Bacteriological Contaminant Sources
Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually the result of a problem with the well, the treatment system, or the pipes that distribute water, and indicates that the water may be contaminated with germs that can cause disease. Fecal Coliform and E-Coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes.

Bacteriological Monitoring Requirements
Public water systems must sample for bacteria in their drinking water monthly or quarterly, depending upon system size, population served, and system type.

Bacteriological Sampling Procedures
As you'll see in the following instructions, the basic instructions for preparing to take a bacteriological sample are known as the three "F"s, ***Flush, Flame, and Flush***. This is a simple way to remember the actions to take prior to collecting a sample.

1. Sampling site(s) must be DNR approved. Use metal faucets if at all possible. Avoid rest rooms or any other sites with higher-than-normal chance of contamin-tion. If mailing sample, determine when the mail leaves thepost office and collect sample just prior to mailing. Plan to mail early in the week and guarantee next day delivery. Avoid weekends and holidays. Plan sampling early in sample period (i.e. early in the month or quarter) to make sure enough time is available for resampling if there are errors or lost samples, and that the results and reports are submitted to DNR before the end-of-period deadline.

2. Without opening it, inspect sampling bottle. If the bottle is damaged in any way or the cap is not fastened securely, discard the bottle and choose another one. Make sure the bottle has been provided by a laboratory and is specifically prepared for bacteriological sampling. If your system adds chlorine for disinfection, make sure the bottle contains a neutralizing agent such as sodium thiosulfate.

3. Remove any attachments that may be connected to the faucet. Also, unscrew and remove the aerator/screen assembly and gasket. Turn on the water, using only the cold water. Allow the water to run approximately 5-6 minutes. The object is to flush out the line to get a representative sample of the distribution system. Longer flushing may be needed if faucet is located a long distance from distribution system.

4. Turn off the water and sterilize the tap or faucet using a propane or butane torch. Hold the flame beneath the opening for 20 seconds, moving the flame continuously to prevent damage.

5. Turn on the cold water and allow it to run at a slow-medium stream for 5 minutes. DO NOT change the flow rate or wash or wipe the faucet before sampling. Remove cap from bottle without touching the inside of the cap or bottle. Hold onto the cap and bottle with your fingers away from the inside edges and away from splashing water. DO NOT set the cap down. DO NOT rinse out the bottle.

6. Without allowing the bottle to touch the faucet, hold the bottle under flow until water is ½ inch from the top. Immediately replace the cap securely. If supplied with a plastic bag, place the bottle in the bag and close the bag, then turn water off. Replace any attachments removed prior to sampling.

Bacteriological Sample Reporting and Delivery

Fill out the sample information form that was included with the bottle, or provided by the DNR (see sample form on page 72 and 73). Make sure you include the system name, type, PWS ID number, county and owner/operator contact information. Also, list the type of sample collected, name of sampler, address where sample was collected, description of sample faucet, whether or not the water is chlorinated, and if so, free chlorine residual at sample location. Make sure you also include collection date and time. Place the sample and completed form in the package supplied, and deliver it to the post office or lab. ***Bacteriological samples must be analyzed within 48 hours of collection***. Check with your post office for the best and fastest way to deliver the sample, or use a different carrier to meet this requirement.

Bacteriological Follow-Up Sampling

Follow up sampling ***IS REQUIRED after ANY TOTAL COLIFORM POSITIVE*** compliance sample. Follow up samples should be collected as soon as possible but in <u>NO</u> case more than 24 hours after being notified of the original positive sample.

Collect samples from sites listed in the DNR approved sampling site plan. If you do not have a DNR approved sampling site plan, contact your local DNR water supply specialist immediately.

- Take 4 follow-up samples within 24 hours: 1- same location (check sample), 1- upstream (repeat), 1- downstream (repeat), 1- in another location (repeat). During the next service month, take 5 samples from any approved locations in the system.

Bacteriological MCL Reporting Requirements
The supplier of water shall report to the department, within 24 hours, the failure to comply with any MCL or monitoring requirements, or treatment technique.

The DNR shall accept analytical data only from certified labs that report **directly** to the DNR. Before contracting with any lab, ensure the lab agrees to report all monitoring results directly to the DNR.

Bacteriological Contamination Health Effects
The presence of bacteria in water can cause symptoms such as nausea, cramps, diarrhea or headaches. For most people, these effects are short-term as their bodies can fight off microbes much the same way as they fight off germs. However, they can be dangerous to infants, elderly, and those people whose immune systems are already weakened.

Bacteriological Treatment Options
Occasionally, long-term bacterial problems are encountered where simple shock chlorination and flushing of the system will not correct the problem. In such cases, the water system owner or operator will be required to upgrade the water system to ensure a continuous safe supply of water is delivered to its customers. If the problem is associated with the source water for the system, installation of a new well may offer a long-term solution to the problem. In cases where a new well is not an option, the following types of treatment have been approved:

- Continuous Chlorination

- Ultra-Violet (UV) Disinfection

- Continuous Ozonation

<u>NITRATES</u>

Nitrate Contaminant Sources
The most common source of nitrates in drinking water is from the use of fertilizers. However, septic tanks, sewage, and decomposition of organic materials are other common sources of nitrate.

Nitrate Monitoring Requirements
Public water systems must sample for nitrate in their drinking water annually or as determined necessary by the DNR.

Nitrate Sampling Procedures
Sampling procedures for nitrates are the same as bacteriological samples, except flaming is not necessary. Also, nitrate samples must be packed with ice when put in plastic bag. Plastic bag should be filled ¾ full with ice and the sample form should be filled out completely (see sample form on following pages). The form should be placed in a separate plastic bag and included in the mailing carton.

1. ***Nitrate samples must be analyzed within 48 hours of collection***. Check with your post office for the best and fastest way to deliver the samples or use a different carrier to meet this requirement.

2. When initial nitrate results indicate the MCL (10 mg/l) is exceeded, the water system operator must collect a confirmation sample within 24 hours of being notified of the original analytical results. Compliance with the nitrate MCL will be based on the average of the initial and confirmation sample results.

3. If the water system operator cannot collect the confirmation sample within 24 hours of receiving the initial nitrate result, the operator must immediately notify all consumers served by the system that the water exceeds the MCL for nitrate. Operators using this option must collect a confirmation sample and have it analyzed within 2 weeks of notification of the original nitrate sample.

Nitrate Reporting Requirements
After receiving the completed sample form from the laboratory, check to make sure that the required (checked items on back of form) testing was done. Make a copy of the results and retain a copy of the completed form for your records. Then, sign and date the form and submit it to the DNR within the following time frames:

- The first ten days following the month in which the result is received, or within;

- The first ten days following the end of the compliance period in which the monitoring was required, whichever is sooner.

- Example: You are required to monitor in the first quarter (Jan, Feb, and Mar) of calendar year 2002. You collect your sample on January 2nd and receive the results on January 30th. You must report the results no later than February10th. On the other hand, if you collect your sample on March 1st and receive the results on March 20th, nitrate results must be received by the DNR no later than April 10th, 2002.

- Report all MCL, monitoring and reporting, and public notice violations to DNR within 24 hours of the time you become aware of the violation.

Nitrate Health Effects
Excessive levels of nitrate in drinking water may cause serious illness and sometimes death. It is especially hazardous to infants as it can interfere with their blood's ability to carry oxygen. The result is a condition called methemoglobinemia or "blue baby syndrome" where the infant literally suffocates due to lack of oxygen to the body's organs and tissues.

Nitrate Treatment Options
When a water system source becomes contaminated with nitrate above the MCL, the water system owner will be required to bring the system back into compliance. Generally, the preferred option is to reconstruct the existing well into a deeper, protected aquifer or drill a new well into a deeper protected aquifer. When an alternative aquifer is not available, the DNR will allow installation of the following approved types of treatment:

- Ion Exchange

- Reverse Osmosis

INORGANIC COMPOUNDS (IOC)

IOC Contaminant Sources
In most cases, the presence of inorganic chemicals in drinking water is caused by the dissolution of minerals in soil, rock and sediment. However, their presence may also be a result of industrial discharges, mining activities, and other practices.

IOC Monitoring Requirements
Public water systems are required to sample for inorganic compounds every 3 years or as determined by the DNR.

IOC Sampling Procedures
Prior to collecting any samples, read and follow all sampling instructions provided by the laboratory.

1. Samples are to be taken at the point of entry into the system (first sampling point after any treatment and before the first customer). All wells represented by the entry point must be running simultaneously during the sampling process and run long enough prior to sampling to ensure a proper mix of all water.

2. Samples should be taken early in the week (on a Monday or Tuesday).

3. If the sample faucet contains an aerator, it must be removed.

4. Run water until cold, or for small systems, until the well pump goes on.

5. Collect samples in appropriate bottles. Immediately preserve samples with appropriate preservatives.

6. Print system name or public water system identification number (PWS ID) on the cap.

7. Complete all sample and request forms (see sample form on pages 80 and 81).

8. Follow laboratory procedures for preservation and shipping.

IOC Sample Reporting Requirements
Upon receipt of the analytical results from the laboratory, check to make sure the required (checked items on back of form) testing was done. Make a copy of the results and retain in your records. Then sign and date the form and submit it to the DNR within the time frames listed below.

- Report routine sample results within 10 days after completion of the test, **OR**

- within 10 days following the month in which the results are received, **OR**

- within 10 days following the end of a compliance period, **whichever of these 3 options is sooner.**

- Report all MCL, monitoring and reporting, and public notice violations within 24 hours of the time when you become aware of the violation.

IOC Contamination Health Effects
The health effects associated with the presence of Inorganic Compounds in drinking water depend on the contaminant and the levels found. Effects may include increased risk of cancer, damage to the liver, kidney, and circulatory systems, or damage to the intestinal or central nervous systems.

IOC Treatment Options
- Reverse Osmosis

- Ion Exchange

- Lime Softening

- Filtration

LEAD AND COPPER

Lead and Copper Contaminant Sources

Although lead and copper are both inorganic compounds that occur naturally in the environment, the most common source in drinking water is household plumbing and fixtures.

Lead and Copper Monitoring Requirements

Public water systems are required to sample for lead and copper every 6 months for initial base monitoring.

Systems not exceeding action levels for two consecutive monitoring periods reduce collection frequency to once per year for two years. If results remain below action levels during both years of annual sampling, monitoring may be reduced to once every three years.

Lead and Copper Sampling Procedures

1. ***Samples must be first-draw after water has been motionless in the plumbing for a minimum of 6 hours***. An exception to the first-draw requirement can be granted to non-transient non-community systems that operate 24 hours per day. They must document that they are 24-hour operations and indicate the approximate length of time the water was motionless before sample was collected.

2. Sample must be from cold, untreated water taps in the kitchen or bathroom of residential buildings. Non-residential building samples must be collected from taps where water is typically drawn for consumption. Taps connected to a softener or other point-of-use-devise may not be used

3. Sample must be acidified immediately after collection. If not, the sample has to stand in the original bottle for 28 hours after acidification.

4. Label bottles and fill out laboratory request forms completely.

Lead and Copper Sample Reporting Requirements

Upon receipt of the analytical results from the laboratory, check to make sure that the required testing was completed. Results must then be entered on the Lead and Copper Sample Form with the results listed from highest (at top) to lowest (see form on page 84). This determines the 90th percentile.

- Complete the Lead and Copper Sample Site Form listing the sites where samples were collected.

- Make a copy of the completed form and keep it with your system records. Send signed, dated, and completed forms to the DNR within the time frames listed below:

- Report routine sample results within 10 days after completion of the test, **OR**

- within 10 days following the month in which the results are received, **OR**

- within 10 days following the end of a compliance period, **whichever of these 3 options is sooner.**

- Report all MCL, monitoring and reporting, and public notice violations within 24 hours of the time at which you are aware there is a violation.

Lead and Copper Health Effects
Elevated levels of lead in the human body can cause serious damage to the brain, kidneys, nervous system and red blood cells. Those at highest risk are young children and pregnant women.

Although Copper is an essential nutrient required by the body, elevated levels can cause stomach and intestinal distress, liver and kidney damage, and anemia. Also, persons with Wilson's disease may be more sensitive to the effects of copper contamination.

Lead and Copper Treatment Options
Lead and copper differ from most other contaminants in that they are not usually found in the source water. These contaminants enter drinking water when corrosive water comes in contact with lead or copper components in the distribution system. Therefore, treatment methods to reduce lead or copper are designed to adjust source water quality to make it less aggressive. USEPA has identified three acceptable treatment approaches for corrosion control:

1. pH adjustment
2. addition of calcium
3. addition of inhibitors (phosphates or silicates)

Any system that exceeds a lead or copper action level must first collect a series of water quality parameter samples to determine baseline water quality. The most appropriate treatment technique can then be selected after determining this baseline.

Some of the treatment options implemented for corrosion control include:

1. Injection of blended phosphates, polyphosphates, or orthophosphates.
2. Injections of sodium silicates
3. Injection of sodium hydroxide
4. Lime contactors
5. Addition of soda ash
6. A combination of the above treatments

It is important to note that in some cases, a small, noncommunity system may be able to reduce lead and copper levels by replacing all plumbing or fixtures that may contribute to elevated levels in the distribution system. This would eliminate the need for constant corrosion control treatment.

VOLATILE ORGANIC COMPOUNDS (VOCs)

VOC Contaminant Sources

The presence on Volatile Organic Compounds in drinking water is usually due to leaking underground storage tanks, discharges from chemical, industrial, or petroleum plants or from the improper disposal of products containing VOCs. The most common source of VOC contamination of drinking water in Wisconsin is leaking underground petroleum storage tanks.

VOC Monitoring Requirements

Public water systems are required to sample for VOCs quarterly for the first year and annually for years 2 & 3. After that, once every three to six years depending on results and susceptibility to potential contaminant sources. If VOCs are detected in the drinking water, increased monitoring is required.

VOC Sampling Procedures

VOCs are point-of-entry samples, which means the sample is taken after treatment and before the first customer. Prior to sampling, evaluate the area around the sample tap for possible air contamination. A loosely sealed or open gas can in a pump house could give off VOCs. Check for recent use of cleaners, solvents, or degreasers, which could taint a sample. Some other products that could possibly contaminate a sample are perfume, cosmetics, skin applied pharmaceuticals, suntan lotion, automotive products, crystalline bathroom/urinal deodorizers and plumbing compounds. If odors from any of these are present, air out the area prior to sampling.

1. If sampling faucet has an aerator, it must be removed. Run water until cold. Reduce flow to a thin stream.

2. Remove cap ring from sample vial, making sure not to lose Teflon liner. If liner falls out, replace it in the cap ring, smooth-Teflon side down, and flush under running water for 30 seconds. For wells that are chlorinated, it is necessary to add ascorbic acid. To add the ascorbic acid powder, give one push of the dispenser/cap to deliver approximately 30mg of acid into the sample vial. Ascorbic acid should be added to each 40ml VOC vial before a chlorinated sample is added. NOTE: Each vial contains 2 drops of 50% HCI. This is a strong acid, do not remove it from vial. Safety glasses and gloves are recommended when taking samples.

3. To minimize the formation of bubbles, fill vial by allowing the water stream to strike the inner wall of the vial. Fill vial with a minimum of splashing to the brim, forming a positive (convex) meniscus at the brim. Do not overflow excessively.

4. Replace the cap by gently setting it on the water meniscus, making sure that the white smooth side of the liner faces down. Tighten firmly. Do not over tighten. The vial cap or neck is easily broken.

5. Turn vial over and check for air bubbles. If there is a bubble larger than the size of a small pea, then resample or quickly add more water.

6. The appropriate boxes on the vial label must be checked to indicate the proper preservatives were added. Repeat the steps for the other vials, opening only one at a time. Add ascorbic acid to the trip blank when it is added to the associated samples.

7. Fill out laboratory request form and sample form (see form on following pages) completely, and include it in the mailing carton. Samples must be shipped on ice.

VOC Reporting Requirements
Upon receipt of the analytical results from the laboratory, check to make sure all required (checked items on back of DNR form) testing was done. Make a copy of the form and keep it with your system records. Finally, sign and date the completed form and submit it to the DNR within the time frames listed below:

- Report routine sample results within 10 days after completion of the test, **OR**

- within 10 days following the month in which the results are received, **OR**

- within 10 days following the end of a compliance period, **whichever of these 3 options is sooner.**

VOC Health Effects
The health effects associated with the presence of Volatile Organic Compounds in drinking water vary depending on the contaminant and the level found. Health effects include the risk of cancer, anemia, liver or kidney damage, or damage to the nervous and circulatory systems.

VOC Treatment Options
- Granular Activated Carbon

- Air Stripping

SYNTHETIC ORGANIC COMPOUNDS (SOCs)

SOC Contaminant Sources
Synthetic Organic Compounds are non-volatile organic compounds commonly found in plasticizers, herbicides and pesticides. In Wisconsin, SOCs most commonly detected in drinking water systems are pesticides and herbicides or their breakdown products. These contaminants are commonly associated with pesticide storage and handling facilities but they may also be associated with agricultural applications and application of lawn treatment chemicals in urban settings. Their presence in drinking water is usually due to the runoff or infiltration of such products into the groundwater.

SOC Monitoring Requirements
Larger systems are required to sample for SOCs twice in 3 years. Smaller systems once in three years.

SOC Sampling Procedures
Sample is taken at point-of-entry, after storage and/or treatment, and before service connections. Sample form 3300-216 “Synthetic Organic Analysis from Commercial Laboratories” will be sent to the facilities by the DNR during the first week of the quarter during which sampling is required (see form on following pages). It is the facility’s responsibility, to order bottles, collect samples, and notify the DNR of the results. The form must be sent to the certified laboratory by the sampler along with the samples. A separate form must be filled out for each sample. It is the responsibility of the facility owner or operator to contract with a lab certified for SDWA SOC testing. Facilities should READ AND FOLLOW sampling and shipping procedures provided by the certified laboratory they have chosen to do the testing.

1. Label each bottle with PWSID# and entry point #.

2. Run water until cold to obtain a representative sample.

3. Fill 1-liter amber bottles to the bottom of the screw cap. 40-ML vials should be filled with no air bubbles. Do not use plastic containers, funnels, or hoses to collect the sample.

4. **One-liter amber bottles contain sodium thiosulfate as a dechlorinating agent.** The 40-ML carbamate vials contain 1.2-ML monochloroacetic acid. Add sodium thiosulfate powder to 40-ML vials if water contains residual chlorine.

5. Samples should be kept cold at all times. To assure that the samples stay cold during transit, freeze the blue ice pack that is enclosed with the 40-ML vials; add water to the 1 liter refrigerant bottle; freeze and replace in mailer. Immediately cool sample bottles by placing in shipper with ice packs or bottle of ice.

6. Complete a SOC lab slip (Form 3300-216) for each entry point. Be sure that all bottles have the same PWS ID and entry point number which appears on the lab slip (might be good to provide an example lab slip with the appropriate information highlighted in color or shaded).

7. Enclose lab slip in a plastic bag.

8. Cool shipping case using a bottle of ice.

9. Seal the shipping cases by completely encircling with strapping tape.

10. Remove the mailing label from the plastic bag on the outside of the box and ship immediately to lab using “Parcel Post-Special Handling.”

SOC Sample Reporting Requirements
Upon receipt of the analytical results from the laboratory, check to make sure the required (checked items on back of the DNR form) testing was done. Make a copy of the completed form and retain with your water system records. Then sign and date the form and submit to the DNR within the time frames listed below:

- Report routine sample results within 10 days after completion of the test, **OR**

- within 10 days following the month in which the results are received, **OR**

- within 10 days following the end of a compliance period, **whichever of these 3 options is sooner.**

- Report all MCL, monitoring and reporting, and public notification violations within 24 hours of the time at which you become aware of the violation.

SOC Health Effects
The health effects associated with the presence of Synthetic Organic Compounds in drinking water vary depending on the contaminant present and the level found. Health effects include the risk of cancer, anemia, damage to the eyes, liver, kidneys, and spleen, and problems with the cardiovascular, nervous, and reproductive systems.

SOC Treatment Options
- Granular Activated Carbon

RADIONUCLIDES

Radionuclide Contaminant Sources

The presence of radioactive elements in drinking water is due to the dissolution of minerals that are naturally occurring in the environment.

Radionuclide Monitoring Requirements

NOTE: New radionuclide regulations will be published in 2002. When new requirements are published, operators will be informed of changes in monitoring requirements, reporting procedures, and new or modified MCLs.

Radionuclide Sampling Procedures

Composite Grab Sample

Sample must be collected from the distribution system from an unsoftened tap. A worst-case sampling location should be used (i.e. nearest the well with highest radionuclide content). If the system is centrally softened, the operator may collect an entry point sample after the softener. A new 1-liter polyethylene bottle, unpreserved is required.

1. Run water until cold.

2. Fill and cap bottle.

3. Print system name (or field number if desired) on cap label. No other information is needed on cap.

4. Complete a Radioactivity Analyses lab slip (Form 3300-220) and request a Gross Alpha test.

5. Place lab form and sample bottle in an appropriate polystyrene field case. Gross Alpha samples can be placed in the same case with inorganics. All forms can be placed in the same pack.

6. Seal field case with strapping tape by completely encircling all four sides of case.

Quarterly Composite Sample

1. Same location as for Gross Alpha sample above. Bottle required is 1-gallon Cubitainer for each composite and must be preserved with nitric acid.

2. Add the first quart of water to the container, using a 1-quart polyethylene bottle, followed by 25ML of concentrated nitric acid (be certain to add the acid only after the quart of water has been added).

3. Add 1-quart of sample to the Cubitainer every three months for the next nine months. Sample should be added without splashing. Rinse off any spatters immediately. Enter

the appropriate date and time on the lab form (Form 3300-220) each time sample is to be added.

Radium Grab (RG) and Radium Quarterly (QC) Sampling

Sample location same as Gross Alpha. Bottle required is 1-gallon Cubitainer.

1. Run water until cold.

2. Fill the container.

3. Add one ampule of concentrated nitric acid preservative.

4. Complete a Radioactivity Analyses lab slip (Form 3300-220) and request a Gross Alpha and a combined Radium 226 and Radium 228 analysis.

5. Ship the sample.

Radon Sampling Procedures

For best results, radon samples should be collected after the well has pumped for a period long enough to allow collection of a representative sample of fresh water from the geologic formation. For small systems, the samples should be collected after the pump has cycled several times. The sample should be collected as close to the source as possible, prior to any treatment or storage, and preferably from the well pump discharge pipe sampling tap. The radon test kit contains a 15-ML glass vial with a two-piece Teflon-lined cap. You will also need a bowl or other container that is at least 3 inches deep.

1. If sample faucet has an aerator, remove it.

2. Run water until cold.

3. Remove the cap from the sample vial, making sure that the liner does not fall out. If the liner does fall out, replace it in the cap so the white Teflon coated side of the liner is not visible when the vial is capped.

4. Place the bowl directly under the faucet and fill, being careful to keep the spigot opening under water after the bowl begins to fill.

5. Fill the bowl to the point of overflowing. Continue adding water for about a minute with the opening of the faucet still below the water level.

6. Submerge the vial in the bowl, open side up, until its fills. At this point, set the bowl down, and put the cap in the water, open end up. While still under water, replace the cap on the vial. Tighten firmly, but do not over-tighten.

7. Lift the closed vial out of the water. Turn the vial upside down and check closely for air bubbles. If there is an air bubble, empty the vial and the bowl and start again.

8. NOTE: As a gas, Radon prefers air to water. With even a small bubble in the vial, some of the radon leaves the water, leaving less radon in the water to measure.

9. Complete the Radioactivity Analysis lab slip (see form on following pages), making sure to include the collection time as well as the date, and all other required data fields.

10. Place the vial and the radioactivity form in the styrofoam mailer. Only the vial should be enclosed in the plastic bag provided. Secure the mailer with tape and attach the mailing label provided.

11. Ship the sample as soon as possible after the vial is filled to the lab, using the best and fastest delivery possible. The sample should be received by the lab no later than 2 days after sampling. The earliest possible receipt of the sample at the lab allows the most accurate radon concentrations to be obtained. Do not let sample freeze.

Radionuclide Sample Reporting Requirements
Upon receipt of the completed sample form from the laboratory, check to make sure that all required (checked items on back) testing was done. Then sign and date the form and submit to the DNR within the time frames listed below. It is recommended that you keep a copy of the completed form for your records.

- Report routine sample results within 10 days after completion of the test, **OR**

- within 10 days following the month in which the results are received, **OR**

- within 10 days following the end of a compliance period, **whichever of these 3 options is sooner.**

- Report all MCL, monitoring and reporting, and public notice violations within 24 hours, of the time when you became aware of the violation.

Radionuclide Health Effects
The adverse health affect typically associated with elevated levels of radioactive contaminants in drinking water is cancer.

Radionuclide Treatment Options
- Reverse Osmosis

- Ion Exchange

- Lime Softening

SECONDARY CONTAMINANTS

Secondary contaminants refer to contaminants that affect the aesthetic quality of drinking water, but do not impact public health (taste, odor, color).

Contaminant	Aesthetics	Treatment
Aluminum	Discoloration of water	Ion Exchange, RO
Chlorides	Taste, odor	Ion Exchange, RO
Copper	Staining	Ion Exchange, RO
Fluoride	Mottling of teeth	Ion Exchange, RO
Foaming Agents	Discoloration	Carbon Filtration
Iron	Taste, odor, color, staining	Filtration, Chlorination
Manganese	Taste, odor, color, staining	Filtration, Chlorination
Silver	Discoloration of skin	Ion Exchange, RO
Sulfate	Taste, odor	Ion Exchange, RO
Total Dissolved Solids	Taste, corrosivity	RO
Zinc	Taste	Ion Exchange, RO

REVIEW QUESTIONS FOR CONTAMINANTS AND SAMPLING PROCEDURES

1. What is the catchphrase for the steps to take to correctly prepare for collecting a bacti sample?

2. What is the sample step used for bacti sampling that is not used for any other type of sampling?

3. If a system is adding chlorine, what must be present in the bacti sample bottle?

4. What is the time frame for which all bacti samples must be analyzed?

5. What does the presence of coliforms in water indicate may also be present?

6. What are the most common sources for nitrates in water?

7. What is the most common health effect associated with higher levels of nitrates in drinking water?

8. Where are Lead and Copper samples collected from?

9. How long must the water be standing in the pipes prior to taking a Lead and Copper sample?

10. When entering the Lead and Copper results on the form, how must they be listed?

11. Where must VOC samples be collected?

12. What is an important action to take with the area around the sampling location before taking a VOC sample?

13. Care must be taken to eliminate what from a VOC sample bottle?

14. What are the common sources for SOC in water?

15. What is added to a SOC sample bottle if the system is adding chlorine?

16. What is the source for radionuclides in water?

17. Where should radiological composite grab samples be collected from?

18. Where should Radon samples be collected from?

Chapter 5
Water System Components
and
Operation & Maintenance

WATER SYSTEM COMPONENTS AND OPERATION & MAINTENANCE

A water system is comprised of different elements including the ***well/pump, water storage facilities,*** and the ***distribution system***. The DNR enforces regulations for design, construction, installation, operation and maintenance of each of these three elements of a water system. These regulations are found in the Wisconsin Administrative Code. For the specific areas of the code for each element, refer to the end of Chapter 1. The complete codes can be found on the internet at www.legis.state.wi.us/rsb/code or by contacting the DNR.

WELL/PUMP

As explained in Chapter 2, the water source for most small water systems in Wisconsin is groundwater. Each type of well or pump has specific maintenance and operation requirements that are not covered in this manual. However, the well owner/operator should consult with their well pump supplier and learn the maintenance requirements for their equipment. There are some general operation and maintenance principals that all operators should follow:

- Keep the area around the well clean and free of all potential sources of contamination. Do not store chemicals or petroleum products near the well.

- Inspect the well frequently. Make sure the well cap is securely in place and that there are no holes or gaps where insects can enter.

- Inspect the well vent screen and make sure it is securely in place.

- Listen to the well while it is running. An experienced operator can identify and solve potential problems by simply listening to the well while it is in operation. In many cases, slight variances in noise are caused by wear to components that could cause system failure.

- Grease pump and motor bearings per manufacturers specifications

- Monitor the water quality. Some changes in water quality are caused by malfunctioning equipment.

WATER STORAGE

Each water system has its own unique requirements for water storage. These depend on such factors as the system's pressure, normal water usage, low and peak demand, and fire protection requirements.

Water storage facilities come in different types including ***ground*** storage, ***elevated*** tanks, ***standpipes,*** and ***hydropneumatic*** or pressure tanks. Depending on their type, they are usually constructed of either steel or concrete. Their primary purpose is to store water during periods of low demand for distribution during periods of high demand. As with pumping equipment, each style and brand of storage facility has its own specific operation and maintenance requirements. Some general operation and maintenance tasks for all storage tanks are:

- Identify and repair storage tank leaks as soon as possible. In a water system, no leak ever repairs itself.

- Inspect the tank for corrosion. It is important to identify and eliminate any corrosion of storage tanks as soon as possible. Left unrepaired, corrosion can lead to failure of the tank and the need for replacement. The easiest way to prevent corrosion is to use protective coatings. Owners may also consider using an anti-corrosion method such as cathodic protection.

- According to Wisconsin Administrative Code, water storage tanks must be inspected every 5 years. Things to look for are cracks, chipped or peeling paint, leaking covers, screens on vents, leaking valves, improperly working gauges and low pressure in pressure tanks.

- Scheduled maintenance should be undertaken when it will least inconvenience customers. If this is not possible, give adequate notification in advance.

WATER DISTRIBUTION SYSTEM

A water distribution system is made up of different components including ***pipes, valves, hydrants, meters,*** and ***treatment equipment***.

PIPES AND MAINS

The common names for the pipes that act as conduits for water to travel through a distribution system are known as ***water mains*** and ***water services***.

Water Mains

Water mains are the pipes that carry water from the source to the storage facilities and throughout the distribution system. They can be made of different materials. The most common are ***ductile iron*** and ***plastic***. However, many older mains were made of galvanized iron, cast iron, concrete, and even wood.

Factors to consider when choosing a main material are its durability, cost, installation, conductivity, and repair and ease of connection for future expansion or customer connection. The material must be approved by the DNR for use in a public water system. Wisconsin Administrative Code requires that pipes used for water mains must be cast iron, ductile iron, reinforced concrete, polyvinyl chloride (PVC), copper, or materials specifically approved by the DNR for restricted or experimental use. All pipes must meet American Water Works Association (AWWA) standards except if approved by the DNR for special low-pressure applications.

Another important factor in choosing water mains is their ***size***. The size of the main will determine how well it transmits water throughout the system. This is due to the fact that smaller pipes allow less water to flow through them due to their size restriction and the friction that is created between the water and the inside walls of the pipe. This loss in flow is called ***friction loss***.

For main sizing, Wisconsin Administrative Code requires that:

- The minimum diameter pipe to provide water for fire protection and supply hydrants shall be 6 inches.

- The minimum flow required for water mains supplying hydrants is 500 gallons per minute (gpm) at 20 pounds-per-square-inch (psi) residual pressure.

- Water mains shall be designed and operated to maintain a minimum residual pressure of 20psi at ground level at all points in the system and under all flow conditions. Normal static pressure shall be no less than 35psi and no more than 100psi respectively at ground level.

- Dead-end mains or other low flow portions of distribution system should be flushed annually or as needed to minimize water stagnation. Water stagnation can lead to unpleasant tastes and odors as well as positive total coliform samples.

WATER SERVICES

The pipes that carry water from the water mains to the customers are called ***services*** or ***laterals***. Today, the most common water service materials are plastic and copper. Many older water services were made of galvanized iron and lead.

As with mains, the sizing of water services is an important factor, and they should be sized according to the needs of the customer. The higher the flows required, the larger the service needed and vice versa.

PRESSURE AND FLOW

One of the most commonly misunderstood areas for customers is the difference between ***water pressure*** and ***water flow***. In many cases, a customer will notify the operator that they do not have any water pressure when, in fact, they are describing a low flow situation.

System pressures will generally fluctuate very little during normal conditions, although low pressure can be caused by high water demand somewhere else in the system or pump or pressure tank problems. Low flow problems can be caused by piping mineral build-up, valves partially closed, the failure to adequately interconnect mains, and pipe fittings such as elbows and tees which cause water to lose velocity as it changes direction. When an operator is faced with a problem dealing with a lack of water, it is important to first identify if it is caused by a lack of pressure or a lack of flow. Once determined, the problem can be fixed quickly and efficiently.

LEAK DETECTION

The most common maintenance problem with water mains and services is leaks. Typically, leaks will occur at points where different pipes interconnect such as elbows, bends, tees, and fittings. However, it is also common for pipes to break due to the earth's natural movement, freezing, or improper installation.

In most cases where there is adequate pressure, water escaping from leaks will generally come to the surface near the location of the leak. However, this may not always be the case when leaks occur on hills, near underground rock crevices or sewer lines, or underneath ground that is frozen. Modern leak detection devices are quite effective at locating such leaks. They typically employ sound-detection devices that locate the leak by detecting the noise pressurized water makes as it escapes from pipes.

Water Hammer

Another cause of broken water pipes is called ***water hammer***. Water hammer occurs when flowing water in a system is immediately stopped due to a valve or hydrant being closed too quickly. This creates tremendous force that can cause considerable damage. Always open and close valves and hydrants slowly.

VALVES

The mechanical devices used to isolate water pipes are called ***valves***. Valves come in a variety of styles, shapes and sizes, but their main purpose is to regulate or stop the flow of water. In a distribution system, there are two types of valves, ***main valves*** and ***service valves***. As their names indicate, main valves are installed on water mains, and service valves are installed on service lines.

Main Valves

Main valves should be located so that shutting one off affects as few customers as possible. They are generally installed at tees or crosses where two or more mains intersect. In many cases they are used to make emergency repairs; therefore it is important to ensure they are accessible and in good working condition. To this end:

- Valves should be operated every 2 years.
- Valve boxes should be kept free of debris so access can be achieved when needed.
- Valves should always be operated slowly to prevent water hammer.

Service Valves

Another name for a valve used to isolate a water service line is a ***curbstop*** valve. They are installed on the service line between a water main and a building, usually near a street curb. As opposed to a main valve, which is used to isolate a section of the water system or main, the curbstop valve is used to isolate a single building. For service valves, operators should:

- Make sure that the locations of curbstop valves are known. Their location should be measured from a nearby building or object.
- Make sure that the service valve boxes are free of any foreign materials and that they are working properly.

HYDRANTS

In a distribution system, the device that allows water to flow quickly out of a main is called a ***hydrant***. Hydrants are generally installed for two purposes, to flush the main and for fire fighting. As such, the hydrants are different.

Flushing or ***blow–off*** hydrants are generally smaller than fire protection hydrants. They are installed on dead end lines and strategically throughout the system in low use areas. Many flushing hydrants are equipped with smaller nozzles unsuitable for fire hose connection.

Fire hydrants are equipped with fire hose connections. They are generally larger than flushing hydrants to allow large volumes of water to flow for fire fighting. They are strategically located throughout a distribution system for ready access in the event of a fire.

Hydrant Styles

Regardless whether they are used for flushing or fire fighting, there are two styles of hydrants, ***dry-barrel*** and ***wet-barrel***.

Wet-barrel hydrants have the operating valve at the top of the hydrant. The entire hydrant contains pressurized water.

Dry-barrel hydrants have a barrel that is empty of water, and the operating valve is located at the bottom of the barrel. This type of hydrant keeps the water below the frost line to prevent freezing. In Wisconsin, virtually every hydrant is a dry-barrel hydrant.

To ensure that hydrants are in working order, an operator should:

- Exercise hydrants every year and keep a record of these operations.
- Maintain hydrants in working order. Hydrants can become hard to operate and may require lubrication. If lubrication is required, follow the manufacturer’s recommendations.
- Always open hydrants fully to close drain holes at bottom of barrel.
- Check hydrants in the Fall to make sure they drain to prevent freezing.
- Operate hydrants slowly to prevent water hammer.

METERS

The devices used to measure water flow and volumes used are known as ***water meters***. There are different types of water meters including ***positive displacement***, ***turbine*** and ***compound*** meters. Meters are always differentiated by size, with the size being the inside diameter of the entry and exit ports.

Positive Displacement Meters

Positive displacement meters measure water as it passes through a measuring chamber. The measuring chamber contains a piston or disc that rotates as the water passes through it. The piston or disc then turns a dial that records the amount of water used. This type of meter is used in normal and low-flow conditions and comes in sizes ranging from 5/8-inch to 2-inches. The 5/8-inch meter is most commonly used in single-family residential applications. The 3/4-inch meter is generally used for large residences, apartments, and businesses, where the service pipe is 1-inch. The 1-inch, 1½-inch, and 2-inch meters are usually installed in businesses, large apartments, hotels, and industrial buildings, depending on water demand.

Turbine Meters

Turbine meters measure water much like a windmill, with the water turning fins or blades as it passes through it. They are generally used in high flow conditions and are not as accurate as positive displacement meters. Turbine meters come in sizes of 2 inches and larger, and are used in hospitals, very large hotels and large industry.

Compound Meters

A compound meter is a positive displacement meter and a turbine meter in one unit. The turbine unit is in the lower part of the meter housing and the positive displacement metering chamber is above it. For normal and low flow conditions, a valve closes and diverts the water through the upper meter. During high flow conditions the valve opens allowing the water to pass through the lower turbine unit. Compound meters come in sizes of 2 inches and larger and are normally used in schools or apartments where substantial fluctuations in water usage occur.

Choosing the Right Meter

In choosing the right meter for a customer, the operator must take into account the low flows, normal flows, and peak flows that the meter will encounter. The accuracy and life of the meter will depend on the type of meter chosen. It is also important to correctly size the meter. The meter should never be any larger than the pipe it is connected to. That's because the size of the pipe will determine the amount of water that can go through the meter.

Meter Reading Methods

Water meters can be read in a variety of ways, depending on the meter style. The most basic style is the ***direct-read*** meter where it is read by looking at the numbers on the top of the meter dial. The number from the previous reading is then subtracted from the present reading to determine the amount of water used between the two readings.

There are also ***generating meters*** that relay the signal from the meter to a registering head mounted at a remote location. Both of these types of meters must be read visually to determine the water usage.

The newer generation of meters is called ***remote-read*** meters. These meters generate a signal from the meter that is read by radio, telephone, or by a hand-held computer. These types of meters allow for readings to be obtained quickly and more efficiently than direct-read and generating meters.

Meter Testing and Repair

In Wisconsin, requirements for the frequency and accuracy of testing for water meters are established and enforced by the ***Wisconsin Public Service Commission (PSC)***. The regulations are important to ensure that both the owner and the customer are correctly compensated and charged for the amount of water used. Although there are conditions which can change the testing frequency, in general:

- Residential meters are to be tested once every 10 years.

- Remote outside meter and automatic meter reading systems are to be tested each time the meter is tested.

- Industrial and commercial meters are to be tested once every 1 to 4 years, depending on size.

- Station meters are to be tested once every 2 years. ***Station meters*** are meters used to measure the amount of water pumped into the distribution system. They should be installed on the inlet line of pressure tanks and storage reservoirs and not on the outlet lines.

- To test a meter, the meter is removed from the building* and placed into a meter testing device through which a known amount of water flows through. This is generally done by using specifically sized tanks. The amount of water that the meter records is then compared to the known amount of water that passes through it. If the meter records the exact amount of water, it is 100% accurate. If not, it will record lower percentages. In general, meters below 95% accuracy should be repaired or replaced.

  *When removing meters, always use a jumper cable to protect yourself. Most buildings' electrical systems are grounded to the plumbing system. Failure to use a jumper cable across the meter setting can result in serious injury or death.

WATER SYSTEM TREATMENT / DISINFECTION

Different methods may be used for disinfection of a water system, including ***chlorination***, ***Ultra Violet (UV)***, and ***Ozone***. By far, the most commonly used method is chlorination. That's because UV and Ozone disinfection systems can only disinfect the water as it passes through them, whereas *residual* chlorine stays in the water and continues to disinfect as it moves through the distribution system.

Chlorination

The addition of chlorine to water is an effective means of disinfecting water for most bacteria. The different forms of chlorine used for disinfection are ***gas***, ***liquid***, and ***solid***. Gas chlorination utilizes pressurized cylinders and regulators that control the amount of chlorine being added (picture at right). Liquid or solid chlorination uses feed pumps that pump the chlorine or dissolved chlorine into the system (picture above right). The length of stroke (size) and number of strokes (speed) control chemical feed pumps. Chlorine feed pumps should be cleaned and flushed with muriatic acid as needed. Hoses should be checked regularly for cracks and deterioration.

Chorine Monitoring

When chlorine is added to the water system, you must to monitor the amount of chlorine added and the levels of chlorine in the system. Common terms associated with monitoring chlorine levels are:

- Residual- Chlorine level after initial reaction.
- Dosage- Amount of chlorine per unit volume of water (i.e. lbs/gallon or mg/liter).
- Chlorine demand- Amount needed to react.
- Free chlorine residual- Amount of chlorine available after the demand.
- Combined chlorine residual- Amount used.
- Total chlorine residual- Total sum of free and combined chlorine.

Chlorine Levels

Water systems that add chlorine must test for the residual amount at the ends of their distribution system twice weekly. The amount of chlorine added must also be monitored daily, either by weight or by volume.

Systems that chlorinate voluntarily should maintain a trace throughout the system.

Systems required to chlorinate must maintain a 0.2 residual at the entry point to the system.

Systems required to perform emergency chlorination must reach a free chlorine residual of at least 0.5 mg/l within 4 hours of DNR notification and maintain it throughout the system.

Chlorine Testing Methods

The usual method for testing chlorine levels in water is known as the colorimetric method, whereby a color reagent, DPD (N-diethyl-p-phenylenediamine), is used. For this method, a measured amount of DPD is added to a specific amount of water.

1. Collect a sample of a known amount of water, matching the amount of the powder packet to the specific volume of water.

2. Add color reagent (powder packet).

3. Match color of sample with a color on the comparator to obtain the chlorine residual.

Chlorine Safety

Chlorine is an extremely hazardous substance if not used, stored, and handled safely. Here are some chlorine safety tips:

- Secure gas cylinders with chains to prevent them from falling over.

- Chlorine should be used in a well-ventilated room.

- Store chlorine in properly labeled containers.

- Do not breath chlorine fumes.

- To detect a gas chlorine leak, spray ammonia around connections. Leaks will form a white cloud when the ammonia reacts with any escaping chlorine gas. For major leaks, leave the room immediately and call 9-1-1 for assistance

Ultraviolet (UV) Disinfection

Ultraviolet disinfection is a method whereby water is passed through a device where it is exposed to ultraviolet light. The UV light can be produced by low-pressure mercury vapor lamps. The amount of UV radiation that the water is exposed to is determined by the number of lamps used and the amount of time the water is in the device.

UV disinfection is effective at disinfecting water containing microorganisms such as protozoans that are resistant to chlorine. Its drawbacks include no residual in the distribution system, effectiveness depends on clarity of the water, and the limitations as to the amount of water that can be treated at one time.

Ozone Disinfection

Ozone disinfection utilizes the addition of ozone (activated oxygen) to the water. As ozone is a powerful oxidizer, it is effective at killing bacteria. Its use is more common in Europe and Canada than in the United States, and like UV, its disadvantage is that it does not leave a disinfecting residual in the distribution system.

WATER TREATMENT METHODS FOR NON-BACTERIOLOGICAL CONTAMINANTS

Lime Softening

Lime softening is used to soften water by adding hydrated lime to precipitate out hardening agents, such as calcium carbonate and magnesium. These materials can then be removed by other processes, usually filtration.

Ion Exchange

Ion Exchange includes cation and anion exchange. Cation exchange is used for water softening whereby the hardness-causing ions such as calcium and magnesium are exchanged with sodium ions. It is also used for removing radium. Anion exchange is used for nitrate and uranium removal. It can also be used for arsenic removal, depending on the arsenic species present and source water quality.

Reverse Osmosis (RO)

Reverse osmosis (RO) is the process where water containing a high concentration of solids is pumped under pressure through a semipermeable membrane. The water that has passed through the membrane is low in solids, leaving behind a waste stream high in solids. Reverse osmosis is quite effective at removing most inorganic contaminants. Membranes with larger pore openings are available to reduce the cost of treatment when the solids content of the water to be treated is lower.

Aeration

Aeration is a process whereby water is mixed with air in a chamber or tower filled with packing material to disperse the water allowing for sufficient contact time. As the water trickles down over the material, air is passed upward “stripping” the contaminants from the water. Aeration or “air stripping” is quite effective at removing volatile organic compounds (VOCs).

Adsorption using Granulated Activated Carbon (GAC)

Adsorption is the process whereby organic contaminants become affixed to the surfaces of granulated activate carbon as it is passed through the carbon bed. In some cases, this process is used in conjunction with aeration to increase the effectiveness of the organic chemical removal.

CORROSION CONTROL

In a water system, corrosion of metallic materials can result from chemical or electrochemical process. Chemical corrosion can be the result of water acidity or the presence of such constituents as carbon dioxide, oxygen, hydrogen sulfide, hydrochloric acid, sulfuric acid and chloride. As corrosion is caused by the water itself, it can occur on any metallic surfaces throughout the water system. Electrochemical corrosion may be caused by the difference in electrical potential between two dissimilar metallic surfaces (electrolysis) or by the presence of a high level of dissolved solids in the water. Both types of corrosion will usually occur at joints or fittings where two dissimilar metals meet.

Methods used to control corrosion in a distribution system include pH adjustment (to make the water less acidic or neutral) or the addition of phosphates. Phosphates, such as orthophosphates and polyphosphates, act to create a microscopic coating on the interior linings of plumbing fixtures. This prevents the water from coming into contact with the metals that can be dissolved into the water. Phosphates are also effective at treating high levels of iron and manganese in the water.

CROSS CONNECTION

Cross connections are connections that link ***potable water*** (water suitable for human consumption) to ***nonpotable water*** (water not suitable for human consumption). Cross connections can cause contamination when a loss in water system pressure allows water to flow back into the distribution system from an outside source. This is called ***back flow*** or ***back siphonage*** and can occur during a water main break or when a main is shut down for repairs. ***Backpressure*** can also occur when a customer's water supply is at a higher pressure than the pressure in the water system. Examples of this could be a power washer with detergent or a boiler system.

Types of back flow prevention devices include ***Air Gap Separation***, ***Reduced Pressure Devices, Double Check Valves, Pressure Vacuum Breakers,*** and ***Atmospheric Vacuum Breakers.***

A good cross connection program includes inspections of buildings to identify existing cross connections, testing of cross connection control devices, record keeping of corrections made, and follow-up inspections.

WATER SYSTEM MAPPING

Water system operators should keep a map of the water system on hand. This can be especially useful when system repairs or upgrades are necessary. Maps do not need to be elaborate, but they should be accurate and up to date. Items that should be listed on maps include streets, valves, hydrants, laterals, water mains, wells and water storage facilities. If possible, sizes, depths and measurements of each item should be included on the maps.

SAFETY

All safety codes for privately-owned water systems are established and enforced by the ***Occupational Safety and Health Administration (OSHA)***. Water system operators should know and follow all safety regulations and manufacturer recommended safety precautions.

REVIEW QUESTIONS ON WATER COMPONENTS FOR OPERATION AND MAINTENANCE

1. Name the three main components of a water system.

2. Name four types of water storage facilities.

3. What are the different components of a water distribution system?

4. What are the two names for the pipes that carry water from the source to the customer?

5. What are the factors an operator should take into account when choosing pipes for a distribution system?

6. What is the difference between water pressure and water flow?

7. What is the name of the reaction that occurs in a water system when a valve or hydrant is closed too quickly?

8. What is the name of the device used in a distribution system to regulate or shut off the flow of water?

9. What are the two main uses for hydrants?

10. Name the three types of water meters and explain what each is designed for.

11. In Wisconsin, what agency regulates the metering of customers?

12. Name the three most common methods used for disinfection.

13. What are the three forms of chlorine available to be used for disinfection?

14. What is the name for the chlorine available in a water system after the demand?

15. What is the biggest drawback of using UV or ozone disinfection?

16. Name two processes used for softening water.

17. Name two methods used for treating corrosion in a distribution system.

18. Name the agency responsible for safety codes at privately owned water systems.

WATERWORKS MATH

Conversions
1 psi (pound per square inch)=2.31 feet of elevation
Minutes in a day=1,440
1 cubic foot of water=7.48 gallons
Weight of 1 cubic foot of water=62.4 pounds
Weight of 1 gallon of water=8.34 pounds
Liters of water in a cubic foot=28.317
Liters of water in a gallon=3.785
12 milligram per liter (mg/L)=1 part per million (ppm)
1 ppm or 1 mg/L=1,000 parts per billion (ppb)
1 ppb=0.001 ppm or 0.001 mg/L
1 million gallons per day (mgd)=694 gallons per minute (gpm)
1 cubic foot per second (cfs)=450 gallons per minute
Water per foot in a 1” pipe=0.041 gallons
Water per foot in a 2” pipe=0.163 gallons
Water per foot in a 4” pipe=0.653 gallons
Water per foot in a 6” pipe=1.469 gallons
Area of a square or rectangle=Length x width
Area of a circle=0.7854 x diameter2
Area of a circle=3.1416 x radius2
Volume of a cylinder=0.7854 x diameter2 x depth
Volume of a square of rectangle=Length x width x depth
Pounds of chlorine needed =Million gallons x ppm x 8.34

Examples
A well pumping 100 gallons per minute can pump how many gallons per day?
(1,440 x 100 = 144,000 gallons)

How many cubic feet are in 20 gallons of water?
(20 x 7.48 = 2.67 cubic feet)

How many cubic feet of water are in a reservoir 20 feet long, 15 feet wide, and 10 feet deep?
(20 x 15 x 10 = 3,000 cubic feet)

How many gallons of water are in this same reservoir?
(3,000 x 7.48 = 22,440 gallons)

How many pounds of chlorine would it take to disinfect this same reservoir to a concentration of 0.5ppm?
(0.022440 x 0.5 x 8.34 = 0.09 lbs)

How many gallons of water are in a circular reservoir that is 30 feet across and 10 feet deep?
(0.7854 x 30^2 x 10 x 7.48 = 52,873 gallons)

With a well that pumps 50 gallons per minute, how long in minutes or hours will it take to fill this same reservoir?
(52,873 x 50 = 1,057 minutes or 17.6 hours)

If you wanted 50 pounds of pressure at a given point of a water system with a gravity feed water reservoir, how many feet above that point must the water in the reservoir be?
(50 x 2.31 = 115.5 feet)

How many gallons of water are in a 2 inches water line that is 400 feet long?
(0.163 x 400 = 65.2 gallons)

If you wanted to flush out that same line through a faucet that flows at 20 gallons per minute, how many minutes would it take?
(65.2 x 20 = 3.26 minutes)

A 2-gallon per minute leak loses how many gallons in a month?
(1440 x 2 x 3 1= 89,280 gallons)

5 parts per million is equivalent to how many milligrams per liter?
(5)

5 parts per billion is equivalent to how many parts per million?
(5,000)

If you had to recoat the bottom of a circular reservoir 20 feet across, how many square feet would you be covering?
(.7854 x 20^2 = 314.16 square feet) or (3.1416 x 10^2 = 314.16 square feet)

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